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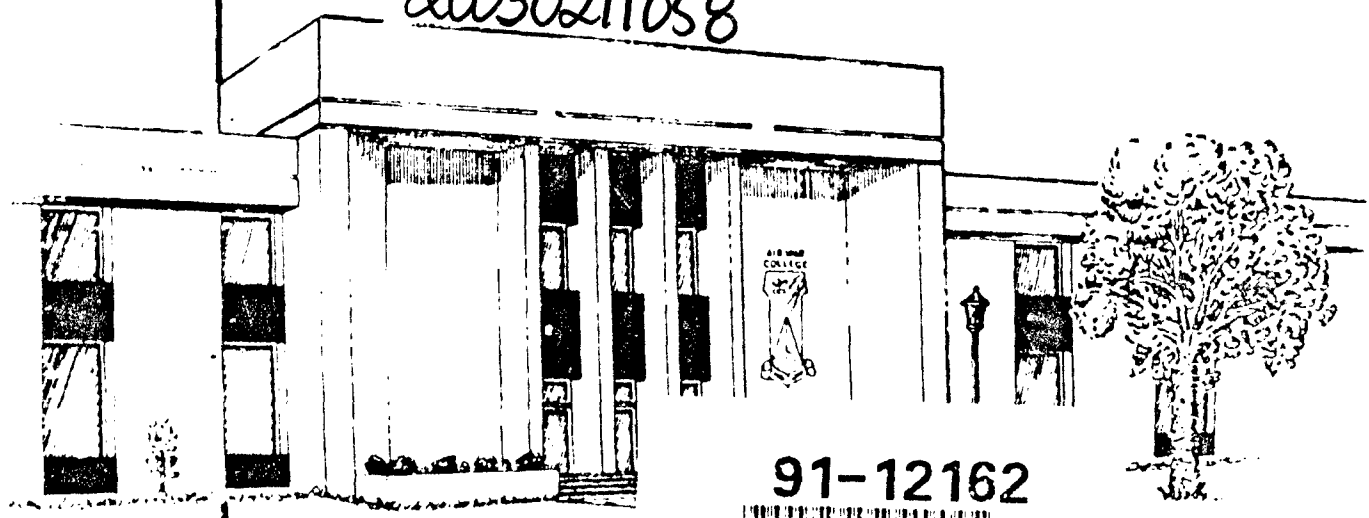
REGIONAL POWER BALLISTIC MISSILES--AN EMERGING
THREAT TO DEPLOYED US FORCES?

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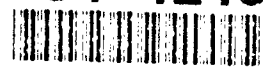
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REGIONAL POWER BALLISTIC MISSILES:
AN EMERGING THREAT TO DEPLOYED US FORCES?

by

John E. O'Pray
Colonel, USAF



A DEFENSE ANALYTICAL STUDY SUBMITTED TO THE FACULTY
IN
FULFILLMENT OF THE CURRICULUM
REQUIREMENT

Advisor: Colonel Eric Sundberg

MAXWELL AIR FORCE BASE, ALABAMA

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EXECUTIVE SUMMARY

TITLE: Regional Power Ballistic Missiles: An Emerging Threat to Deployed US Forces? **AUTHOR:** John E. O'Pray, Colonel, USAF

This analytical study addresses the issue of whether proliferation of ballistic missiles among potentially hostile regional powers poses an emerging threat to deployed US forces. Five regional powers are identified as potentially hostile: Iran, Iraq, Libya, Syria, and North Korea. This assessment addresses four questions: missile availability; target accessibility; targeting accuracy; and warhead effectiveness.

Ballistic missile technology has proliferated so extensively that the potentially hostile regional powers could develop or acquire missiles with ranges from 900 km to over 3,000 km. Iraq is developing missiles with ranges of 2,000 km and beyond, and North Korea is producing copies of the Soviet SCUD-B. Potentially hostile regional powers could already target several deployment bases with SCUD-Bs and extended range SCUDs.

Missiles which will be available to potentially hostile regional powers well before the year 2000 could target US deployment bases throughout the North Africa/Middle East/Southwest Asia and Northeast Asia regions. Some of the warhead options available to those powers would be effective for the range of missile accuracies projected. Chemical warheads already accessible to potentially hostile regional powers would be effective at any accuracy level considered, and other warhead options such as submunitions would be effective at the highest accuracy level.

BIOGRAPHICAL SKETCH

Colonel John E. O'Pray has served in a series of assignments related to ballistic missile defense and ballistic missile development. He is an Aeronautical Engineer with three degrees from the California Institute of Technology (CalTech). As Chief of the Design and Analysis Section at the Air Force Rocket Propulsion Laboratory (now the Astronautics Laboratory), he directed performance analysis for strategic and tactical missile systems and demonstrations of advanced rocket propulsion technology.

At the Air Force Weapons laboratory, he managed laser technology demonstrations and laser system design studies for applications including defense against strategic and tactical missiles. As a staff officer at Headquarters, Air Force Systems Command, he was responsible for the Air Force laser technology program. He also participated in the Department of Defense Space Laser Study that preceded the Strategic Defense Initiative.

Most recently, at Space Systems Division he managed system design and technology demonstrations for space based defenses against ballistic missiles. He served as Deputy Program Manager for the Strategic Defense Weapons System Program Office (SPO) and as Program Manager of the Directed Energy Weapons SPO. Colonel O'Pray is a graduate of the Air War College, class of 1990.

TABLE OF CONTENTS

DISCLAIMER	11
EXECUTIVE SUMMARY	111
BIOGRAPHICAL SKETCH	1v
Chapter	
I. INTRODUCTION	
Prominence of the Regional Power Ballistic Missile Issue	1
Objective and Scope of the Analytical Study	1
Overview of the Potential Ballistic Missile Threat	4
Structure of the Analytical Study--the Four Questions	7
II. MISSILE AVAILABILITY--BALLISTIC MISSILE PROLIFERATION	
AMONG REGIONAL POWERS	10
Terminology and Approach	10
Missile Exports from the USSR	11
Missile Production and Development	
by Potentially Hostile Regional Powers	17
Missile Proliferation from Nonhostile Regional Powers	25
Missile Availability Summary	32
III. TARGET ACCESSIBILITY.	34
North Africa/Middle East/Southwest Asia Region	35
Northeast Asia Region.	42
Target Accessibility Summary	46
IV. TARGETING ACCURACY FOR REGIONAL POWER BALLISTIC MISSILES	47
Introduction to Targeting Accuracy Assessment	47
Missile Inertial Guidance Accuracy	48
Launcher Geolocation.	60
Target Geolocation	62
Targeting Accuracy Summary	68
V. MISSILE WARHEAD EFFECTIVENESS	69
Introduction	69
High Explosive Warheads	72
Chemical Warheads	74
Submunition Warheads.	81
Nuclear Warheads	87
VI. CONCLUSIONS	91
LIST OF REFERENCES	94
GLOSSARY	101

CHAPTER I

INTRODUCTION

Prominence of the Regional Power Ballistic Missile Issue

This analytical study addresses the question of whether the proliferation of ballistic missiles among potentially hostile regional powers poses an emerging threat to US forces deployed overseas. This potential threat from regional power ballistic missiles is becoming a high visibility issue for US defense policy.

Authoritative public testimony by the Director of Central Intelligence (DCI), Judge William Webster, has highlighted this issue. In March 1989, the DCI testified to the Senate Governmental Affairs Committee that "By the year 2000, at least 15 developing countries will be producing their own ballistic missiles," and that some of them were developing chemical, biological, or nuclear warheads for those missiles. (1:14,15) As the leadoff witness before the Senate Armed Services Committee hearings in January 1990, Judge Webster amplified his previous testimony:

Most missiles likely to be fielded in the third world over the next five years will have ranges less than 1,000 km. But by the year 2000, at least six countries probably will have missiles with ranges up to 3,000 km. At least three of them may develop missiles with ranges of up to 5,500 km. (2:30)

Judge Webster also testified that four of the nations developing missiles already have or are close to acquiring nuclear weapons capabilities and, "By the end of the decade, four more countries could be added to the nuclear list." (3:11)

The reality of ballistic missile warfare by regional powers was graphically demonstrated when Iran and Iraq engaged in the most extensive combat use of ballistic missiles since Hitler's V-2 missile attacks against English cities and allied ports in World War II. (4:1427; 5:38-40) Over 600 large ballistic missiles with warheads weighing up to a metric ton were fired, primarily at the opposing capitals, during the "War of the Cities" in early 1988. (4:1427) According to the DCI, the Iraqi missile attacks triggered the flight of a sizable portion of the population of Teheran, and they were widely perceived as a major factor in coercing Iran into agreeing to a cease fire. (1:14)

The Commander in Chief of U.S. Central Command (CINC USCENTCOM), General Schwarzkopf, stated in March 6, 1990 testimony for the Senate Appropriations Committee that:

An increasingly significant threat to the military balance in the region is the emergence of long-range missiles and nuclear, biological and chemical arms development and proliferation. The employment of chemical munitions as anti-personnel weapons and the extensive use of SCUD missiles in the "War of the Cities" have driven more moderate non-belligerent neighbors to perceive a need to obtain similar capabilities as deterrents. This accelerated upgrading in the quality, lethality and range of these types of arms contributes to both military and political instability. (6:4)

Most of the missiles fired in the "War of the Cities" were copies and extended-range derivatives of the Soviet SS-1C "SCUD B" which are now in serial production by regional powers. (4:1423-1427) Although the missiles targeted on Teheran and Baghdad were not armed with chemical warheads, the extensive use of nerve gas and other lethal agents during the Iran-Iraq War shattered the previous international inhibitions against chemical warfare and alarmingly increased the destructive and coercive potential of ballistic missile attacks. (7:2-3)

The issue of ballistic missile proliferation among regional powers became increasingly prominent in high level US government statements between 1988 and 1990. These statements highlighted the fact that, because of the growing indigenous arms production capability of the regional powers, the proliferation of ballistic missiles was increasingly beyond the control of the superpowers. The National Security Strategy of the United States approved by President Reagan in January 1988 identified "... the diffusion of economic power and advanced technology to the Third World" as one of the three major world trends and stated that:

This combination of economic growth and technological maturation has already provided several countries with an independent capability to produce large numbers of advanced weapons systems, both for their own use and for export. Thus, countries dependent on neither the United States nor the Soviet Union could in the not too distant future possess the capability to conduct a major war, either against each other or against a world power. The arsenals at the disposal of these sovereign countries are likely to include chemical weapons, and may eventually include nuclear weapons and space systems for target location. (8:9) [boldface added]

The updated National Security Strategy approved by President Bush in March 1990 specifically highlighted the threat that regional power ballistic missiles pose to deployed US forces:

The spread of ever more sophisticated weaponry - including chemical, biological, and nuclear weapons - and of the missiles capable of carrying them represents a growing danger to international security. This proliferation exacerbates and fuels regional tensions and complicates U.S. defense planning. It poses ever greater dangers to U.S. forces and facilities abroad, and possibly even to the United States itself. (9:17) [boldface added]

On one occasion, regional power ballistic missiles have actually been fired at US forces. As the DCI confirmed in his 1989 testimony, following the US air strikes in 1986, Libya retaliated by firing two missiles against a US detachment on the Italian island of Lampedusa near

Sicily. (1:16) Fortunately, both of the SCUD-Bs missed the Navy LORAN station on the small island, apparently by less than a mile. (4:1427)

Objective and Scope of the Analytical Study

The objective of this analytical study is to provide a top-level assessment of the potential threat from regional power ballistic missiles in order to stimulate further analysis and professional dialogue. The intent is to catalyze vigorous discussion of the implications of this emerging threat for future US force structure and force deployment and employment in regions where ballistic missiles are proliferating. In order to broaden dissemination and facilitate this professional dialogue, this study has been kept unclassified and is based entirely upon open literature sources. Fortunately, because of the high visibility of the ballistic missile threat issue for both regional power and NATO scenarios, substantial amounts of authoritative unclassified information have been published by the Department of Defense or released in high level Congressional testimony such as the DCI and CINC USCENTCOM testimony cited above. Furthermore, because this is a top level assessment of an emerging threat, there is no need to delve into potentially sensitive details of current threats to specific US forces. Authoritative US open literature and respected international publications are also cited.

The temporal focus of this analytical study is on the ballistic missile threat between 1990 and the year 2000. Because of the uncertainty in projecting missile development by the regional powers out to the year 2000, the assessment of the nearer term threat will be more detailed.

This analytical study is focused on the potential threat to US forces deployed overseas from ballistic missiles fired by five potentially

hostile regional powers in two regions: Iran, Iraq, Libya, and Syria in the North Africa/Middle East/Southwest Asia region; and North Korea in the Northeast Asia region. The designation of five powers within those two regions as potentially hostile is based on a judgmental assessment that the current state of international relations between the United States and those regional powers is strained or confrontational and has a generally recognized potential for deteriorating into armed conflict.

Based on that assessment, the powers designated as potentially hostile within the North Africa/Middle East/Southwest Asia region are Iran, Iraq, Libya, and Syria. In discussing the regional ballistic missile threat during a March 1990 interview with the London Times, Vice President Quayle stated that ". . . these are countries that are not always friendly to Western interests--Iraq, Iran, North Korea . . . if you put a ballistic missile in the hands of Gadaffi or somebody that is cavalier about starting a conflict, then you've got problems." (10:17)

In the Northeast Asia region, North Korea is designated as a potentially hostile regional power for this study. In a February 1990 speech, Secretary of Defense Cheney warned that the threat from North Korea remains ". . . very high", and he commented that "If there's one place in the world where as Secretary of Defense I get up in the morning worried about the possibility you could have a short-warning or a no-notice attack against US forces, it's in Korea." (11:7)

This study will not directly address the potential use of regional power ballistic missiles in intraregional conflicts that do not threaten deployed US forces. However, as will be addressed in Chapter III, the missile range needed to satisfy those intraregional targeting requirements determines the missile development or acquisition goals of the regional

powers and thereby affects which US deployment bases are within range. The primary motivation for ballistic missile competition among regional powers has been the perceived effectiveness of those missiles in deterring or fighting intraregional conflicts such as Iran versus Iraq, Syria versus Israel, India versus Pakistan, or North Korea versus South Korea. As General Schwarzkopf testified in March 1990, "Iran and Iraq, along with several other states in the region, are now actively engaged in a missile arms race which can threaten the military balance in Southwest Asia."

(6:36)

The threat assessment in this study is limited to inertially guided ballistic missiles with ranges from 300 km to approximately 3,200 km. The rationale for selecting this range category will be presented in Chapters II and III. These are the missiles that add a "new dimension" to regional conflicts because they could reach far beyond the battle area and attack deployed US forces at bases which had previously been considered sanctuaries. The relatively short time-of-flight of these missiles and the impotence of antiaircraft defenses against them contribute to this "new dimension" of the threat. (7:7,11) This study excludes both shorter range "battlefield" missiles which generally cannot threaten US deployment bases and the regional power aerodynamic missiles which resemble traditional aircraft threats. As the DCI testified:

... we judge that ballistic missiles will be the preferred delivery system of many nations because they cannot be defended against as effectively as artillery or aircraft. For that reason, the deterrent value of ballistic missiles is higher. Furthermore, they are more prestigious than conventional systems. (1:16)

This analysis of the potential ballistic missile threat to US forces already deployed in or deploying to these two regions will be focused on the missile threat to air bases. Both Air Force operations

within the regions and the deployment or reinforcement of Army forces are critically dependent upon the availability of regional air bases. Furthermore, as will be delineated later in this study, the regional air bases that US forces depend on are high value, fixed, large area targets that are particularly appropriate targets for attacks by ballistic missiles. The potential ballistic missile threat to other US assets in the regions such as storage depots for Army prepositioned supplies and Navy port facilities will also be addressed.

Overview of the Potential Ballistic Missile Threat

Several factors contributed to the increasing concern at the highest levels of the US government over ballistic missile proliferation among regional powers. Previously, regional powers could only obtain ballistic missiles from the United States, the Soviet Union, China, or France. Therefore, because the major powers retained control over the flow of spare parts, replacement missiles, and training, they were able to exercise some degree of control over the employment of the missiles they transferred. Now, in contrast, ballistic missile technology is widely disseminated among the regional powers. Regional powers that are potentially hostile to the United States such as North Korea, Iraq, and Iran are now either producing copies or extended range derivatives of Soviet ballistic missile designs or are obtaining those missiles from other potentially hostile powers. Furthermore, nonhostile regional powers such as Brazil and Argentina are actively developing new ballistic missile systems and offering to export those missiles to potentially hostile regional powers. (1:14-16; 4:1423-1427; 7:1,4,23)

Advances in the ballistic missile and warhead technologies available among regional powers also contributed to the increasing concern. The extended range derivatives of Soviet missile designs developed in the Third World brought many more potential targets into range. Probably the most important factor contributing to the increased concern is the proliferation of improved warhead technologies including chemical, fuel-air explosive, submunition, and potentially nuclear warheads which greatly increased the potential destructiveness of the missiles. Furthermore, this dramatic increase in warhead effectiveness is widely perceived as compensating for the accuracy limitations of the missile guidance systems available among the regional powers. (1:14,16:12:347)

In addition, the potential use of commercially available satellite data to enhance missile targeting has been highlighted as another factor contributing to the increased concern about missile proliferation. (8:9) This exploitation of commercial space data could potentially dramatically reduce the uncertainties in missile launcher and target location which had previously been assumed to be major limitations on the overall accuracy and effectiveness of regional power ballistic missiles. For example, one potential space targeting enhancement is the use of radio navigation satellite data to significantly reduce the uncertainties in the positions of both the mobile missile launchers and the targets. A second possibility for space targeting enhancement is the use of commercial imagery from the French SPOT satellites for target geolocation and damage assessment. (13:22; 14:8-10; 15:14)

Structure of the Analytical Study--the Four Questions

This study is structured to sequentially answer four questions that must be addressed in assessing the ballistic missile threat: missile availability; target accessibility; missile targeting accuracy; and warhead effectiveness. The first question is missile availability: what types of ballistic missiles will be available to the potentially hostile regional powers between 1990 and the year 2000; and what will their range and payload characteristics be? The second question is target accessibility: can those missiles reach bases where US forces probably will be deployed? The third question is missile targeting accuracy: what is the basic accuracy of those missiles; and can commercial satellite data be exploited to enhance overall missile targeting accuracy? The fourth and final question is warhead effectiveness: given the overall missile accuracy and the warhead technologies available; could those warheads effectively threaten deployed U.S. forces, particularly at overseas air bases?

CHAPTER II

MISSILE AVAILABILITY--

BALLISTIC MISSILE PROLIFERATION AMONG REGIONAL POWERS

Terminology and Approach

This chapter addresses the first question of missile availability: what types of ballistic missiles will be available to the potentially hostile regional powers between 1990 and the year 2000; and what will their range and payload characteristics be?

The term "Regional Power Ballistic Missile" or "RPM" has been adopted to categorize the missiles addressed in this study because the terminology used to categorize different classes of ballistic missiles has varied widely in different periods and regional contexts. In the era of the bipolar ballistic missile competition between the United States and the USSR in the 1950s and 1960s, the designation Intercontinental Ballistic Missile (ICBM) was applied to missiles with ranges of approximately 5,000 nmi (9,267 km). Missiles with ranges of nominally 1,500 nmi (2,780 km) such as the Thor were designated as Intermediate Range Ballistic Missiles (IRBMs). As several types of ballistic missiles with ranges between a few hundred and a few thousand kilometers were deployed with NATO and Warsaw Pact forces in the 1970s and 1980s, the generic term Theater Ballistic Missiles or Tactical Ballistic Missiles (TBMs) was applied. (16:1-3) In the US and Soviet arms control negotiations, the class of missiles with ranges between 500 and 1,500 km was designated as Intermediate-Range Nuclear Forces (INF). This entire class of missiles is being eliminated from US and Soviet arsenals under the INF Treaty. (17:48-50) In this NATO/Warsaw Pact context, the term

Shorter-range TBMs was applied to missiles with ranges below the 500 km INF Treaty threshold.

However, ballistic missile arsenals of the regional powers are not constrained by the INF Treaty between the United States and the USSR. As will be detailed below, ballistic missiles already deployed by or under development by the regional powers span the range from "Shorter-Range TBMs" through the "INF" class to what were historically termed "IRBMs". The key distinguishing characteristic of all these missiles (and the motivation for this study) is that these missiles are controlled by the regional powers rather than by the major powers that initially developed ballistic missiles. Therefore, the term Regional Power Ballistic Missile (RPBM) has been adopted for this study.

There are three sources for the RPBMs that are becoming available to the potentially hostile regional powers: first, RPBM exports from the USSR; second, RPBM production and modification by the potentially hostile regional powers; and, third, RPBM proliferation from nonhostile regional powers. These three sources of RPBMs will be addressed in turn in subsequent sections. As will be illustrated, the cross-proliferation of RPBM technology and missiles among both potentially hostile and nonhostile regional powers is very extensive.

Missile Exports From the USSR

Most of the RPBMs currently deployed by the potentially hostile regional powers are copies or modifications of the Soviet SS-1C "SCUD-B" (NATO designation). Reflecting the Soviet emphasis on tactical ballistic missiles, this relatively unsophisticated but effective missile design which entered service in the early 1960s was mass produced for deployment

with the Warsaw Pact and for export. The SCUD-Bs were well regarded throughout the Warsaw Pact and were deployed with Bulgarian, Czech, East German, Hungarian, Polish, and Romanian as well as Soviet forces. (14:127) The 1985 edition of Soviet Military Power noted that over 575 SCUD launchers were deployed including over 100 in the Far East and about 75 opposite Southwest Asia and eastern Turkey. (19:38) The SCUD deployments are highlighted to emphasize not only the producibility and deployability of the SCUDs but also the Soviet doctrinal emphasis on tactical ballistic missiles which clearly influenced the potentially hostile regional powers.

As the DCI testified, the Soviets widely exported the SCUD-B to Middle East nations including Syria, Libya, and Egypt. (1:14,16) According to International Defense Review (IDR), the special export version of the SCUD-B (designated the R-17E) was initially developed at the request of those three client states, and the first shipments went to Egypt (then a Soviet client) in 1973. (4:1423) The export version included a one metric ton (1,000 kg or 2,200 lb) high explosive warhead, and it was launched from the same high mobility Transporter-Erector-Launcher (TEL) as the Soviet R-17s. (4:1426) However, the export version has a manual command and control interface in place of the automated fire control system of the Soviet version. (4:1423)

All five of the potentially hostile regional powers addressed in this study received Soviet SCUD-Bs. According to IDR, the extensive Soviet exports of the R-17E included the following shipments of TELs: Syria, 18; Libya, 72; North Korea, 24; Iraq, 36; and Egypt, 24. (4:1423) In addition, Iran apparently obtained an initial two TELs and 30 SCUD-Bs from Libya in 1985 and a small number of additional missiles plus technical assistance from Syria in 1986, but these missiles were soon

expended. (20:129,130;4:1424) These extensive Soviet exports of TELs and missiles are a measure of both the extent of RPBM proliferation and the potential multiple launch missile firepower of the regional powers.

Additional exports of Soviet SCUDs reportedly were Iraq's primary source of SCUDs during the Iran-Iraq war. In 1986, Iraq apparently received a major shipment of approximately 300 of the R-17E export version of the SCUD-B. (4:1425) Although the Soviet Union initially denied supplying SCUDs to Iraq, the Soviets subsequently admitted selling standard SCUD-Bs, but denied assisting Iraq with the modifications to extend the SCUDs range that will be discussed below. (7:53)

SCUD Development History

Because the SCUD-B provided most of the missile hardware and missile technology base that is currently proliferating among the regional powers, it is appropriate to describe the development history of this missile and some of the key design features. In addition, key regional power personnel who will influence development of RPBMs were trained by the Soviets on SCUD hardware and technology.

The SCUD-B exported to the regional powers was a relatively mature, "second generation" design from an ongoing SCUD missile development program that produced incrementally improved SCUD versions over a period of more than 30 years. The SCUD-B which began development in 1955 and was first deployed in 1961 was a longer range, more accurate upgrade of the "first generation" SCUD-A with a range of 180 km that had first been deployed in 1955. (4:1426) The nominal range of the SCUD-B is 300 km according to Soviet Military Power 1989. (17:50) Another version designated the SCUD-C with range extended to 450 km but with degraded accuracy was reported deployed in limited numbers beginning in 1965.

(18:127; 4:1426) A fourth and final version designated the SCUD-D was developed in the early 1970s specifically to deliver warhead "buses" with multiple submunitions more accurately, and this version entered service in the early 1980s. (4:1426) Although these SCUD-C and SCUD-D versions are not reported to have been exported to regional powers, the regional power personnel trained by the Soviets on the SCUD-B export version may have learned at least the design approaches and perhaps the specific modifications for range extension and submunition warheads.

Development of the SCUD series of TBMs then ceased in favor of the longer range (500 km), more accurate, solid fuel SS-23 SPIDER. (21:54,55; 17:50;4:1426) However, the INF Treaty is now eliminating the SS-23s, and Soviet Military Power 1989 states that the Soviets are reintroducing SCUDs into TBM units as SS-23s are withdrawn. (17:67,142)

SCUD-B Design--Basis for RPBM Proliferation Among Regional Powers

The SCUD-B is a single stage, inertially guided ballistic missile fueled by storable liquid propellants. The missile body is a cylindrical metal structure with integral propellant tanks. The propellants are pumped from these low pressure tanks into the single rocket engine by a turbine powered pump. Missile thrust vector control (steering) is accomplished by graphite vanes which protrude into the rocket exhaust to deflect the flow in response to steering commands from the guidance system. The simplified inertial guidance system uses a standard design approach with three gyroscopes. The warhead separates after booster thrust termination to improve warhead reentry accuracy. (4:1426)

The relatively simple design of the SCUD-B make production of that missile and its derivatives feasible for regional powers with a moderately advanced aircraft and missile industrial base. Many of the SCUD-B design

features are directly traceable to the World War II German V-2. (5:68-80; 22:1909,1910) For example, fabrication of the metal airframe with its low pressure tanks is straightforward. Graphite vanes were generally used for missile thrust vector control from the V-2 up through the US Army's REDSTONE TBM in the mid-1950s. (5:78-80) Although the protruding vanes create shock wave losses in the exhaust flow that moderately degrade the overall rocket performance, vanes are simple to fabricate and avoid the complexity of gimbaling the rocket engine for thrust vector control. (23:463) The turbopump for propellant injection allows lightweight, low pressure tanks for the SCUD-B instead of the heavy, high pressure tanks required for the gas-pressurized propellant feed system of the SCUD A. (23:445-461; 4:1426) Furthermore, the 1960 vintage turbopump of the SCUD -B is descended from the V-2 design and does not require technologies beyond those available to the more advanced regional powers in turbine engines, turbocompressors, and turbosuperchargers. (5:77;4:1426)

The SCUD-B Transporter-Erector-Launchers (TELs) provide missile launch platforms with high off-road mobility which could be widely dispersed throughout the territory of potentially hostile regional powers. The TEL is based on a modified Soviet eight wheel drive (8X8) heavy truck chassis. The missile is transported horizontally on the TEL and then elevated to the vertical position for fueling, guidance alignment, and firing from a simple folding launch pad at the rear of the TEL. A Soviet SCUD-B on a TEL is shown in Figure 1. The nominal time required for erecting the missile, fueling, and aligning the guidance system for firing is one hour. Additional support vehicles required for SCUD-B units include: fuel and oxidizer tanker trucks with pumps for propellant transfer; a crane truck for missile reloads; a mobile meteorological unit

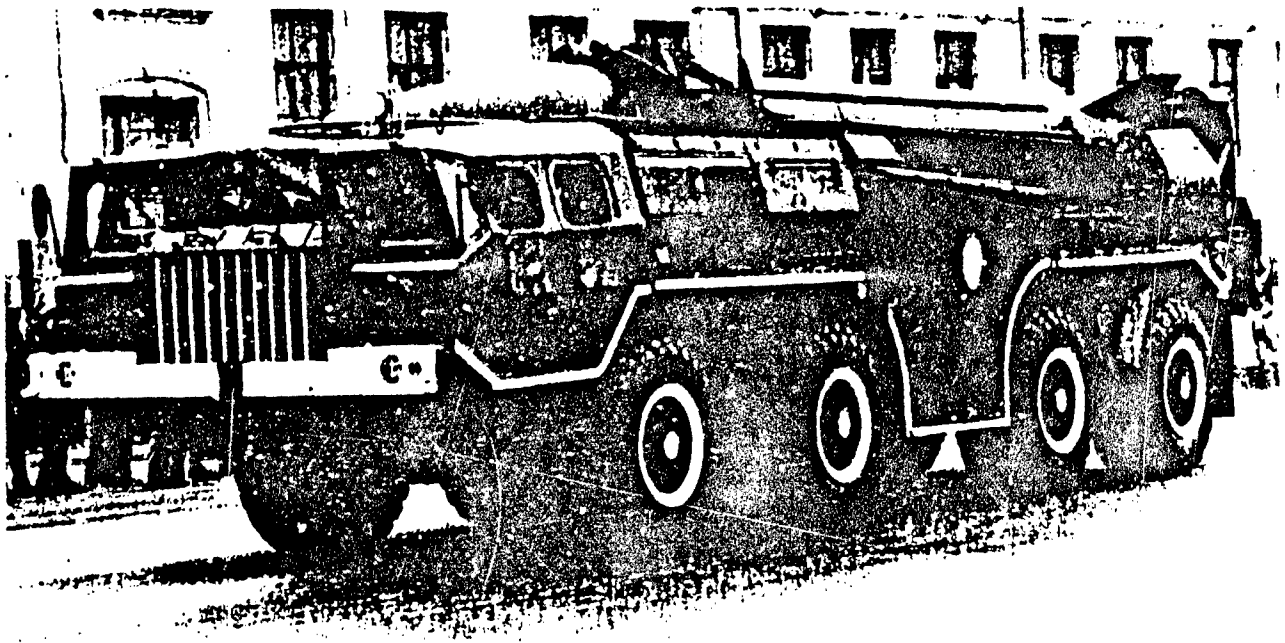


Figure 1. Soviet SCUD-B on Transporter-Erector-Launcher (TEL)

(Soviet Military Power 1985, p74)

with a weather radar; and command and control vehicles. (4:1426,1427; 18:1427)

The SCUD-B propellants are traditional liquid rocket propellants that are storable in standard, uninsulated chemical storage tanks over a wide ambient temperature range for long periods. (23:371; 24:102) The rocket fuel is Unsymmetrical Dimethylhydrazine (UDMH), and the oxidizer is Inhibited Red Fuming Nitric Acid (IRFNA). (4:1426) These propellants are available on the international market or are producible by regional powers with moderately advanced chemical engineering industries. However, these propellants are highly toxic, and SCUD missile fueling crews wear chemical protective clothing. (18:127; 4:1426) Therefore, arming SCUDs with chemical warheads does not add a new dimension to the operational procedures and hazards for the missile crews.

Missile Production and Development

By Potentially Hostile Regional Powers

The most significant recent development in the ballistic missile proliferation arena is the mounting evidence published in 1989 and early 1990 that the potentially hostile regional powers have now acquired significant indigenous missile production and development capability. This study's assessment therefore differs from the perspective of most earlier studies such as the Congressional Research Service report Missile Proliferation published in October 1988. That report emphasized the limited aerospace industrial capability of the potentially hostile regional powers and their dependence on missile hardware and technology from Western powers and the nonhostile regional powers such as Brazil and Argentina. (7:1,2,4,55) In contrast, as is detailed below, North Korea

has produced hundreds of SCUD-B copies, and Iraq developed and fired in combat extended range SCUD derivatives with two to three times the range of the original SCUD-B. Furthermore, Iraq has tested an IRBM class (1,500 nmi range) missile and has publicly released video tape of the test flight of a three stage booster stated to be capable of launching a satellite.

This proliferation of SCUDs and extended range SCUD derivatives was stimulated by the intense demand for missiles to replace the hundreds being fired in combat during the Iran-Iraq war. Reportedly, SCUD and SCUD derivative missile firings between 1982 and May 1988 totaled 636, with 424 of those launches during the first five months of 1988. Of those totals, Iraq fired 361, and Iran launched 271. (4:1427; 20:130,131) This intense demand triggered a three faceted proliferation of SCUD supplies to the regional powers: first, lateral transfers among regional powers of SCUDs previously exported by the Soviets; second, additional exports of Soviet SCUDs; and, third, production of SCUD copies by regional powers. Lateral transfers among regional powers and new Soviet exports were not adequate to replace combat firings, and regional powers began producing SCUD-B copies themselves.

Soviet refusal to export longer range TBMs was apparently the major stimulus for the efforts by regional powers such as Iraq to develop longer range SCUD derivatives or to acquire longer range missiles developed by other, non hostile regional powers. Although Iraq, Syria, and Libya all reportedly requested longer range missiles, the Soviets refused to export either the 900 km range SCALEBOARD or the SS-23, the 500 km range "third generation" SCUD replacement. (4:1427; 25:17; 26:298,302) Any Soviet exports of the SCALEBOARD or SS-23s could have been interpreted by the

United States as an attempt to circumvent the INF Treaty requirement to destroy missiles with ranges between 500 and 1,500 km.

North Korea: RPBH Production and Development

Production of SCUD copies by North Korea, one of the potentially hostile regional powers, was apparently Iran's primary source of missiles during the Iran-Iraq war. As the DCI, Judge Webster, testified in 1989:

The Soviet Union has been a traditional supplier of short-range ballistic missiles. It has sold SCUD-B missiles widely in the Middle East. Ironically, the Soviets may soon be competing with an old client, North Korea, which now manufactures its own copy of the SCUD. (1:14)

The North Korean program to "reverse engineer" the SCUD-B and produce copies began in 1976 in collaboration with Egypt, but progress was apparently slow due to funding constraints until an infusion of Iranian funding in mid-1985 reinvigorated the program. (27:177) The People's Republic of China (PRC) reportedly provided significant technical assistance for the North Korean program, and some rocket engine and guidance components for the SCUD copies may be imported from the PRC. (27:177,178) In January 1987, the South Korean Defense Minister announced that North Korea had test fired a "long range" ballistic missile, presumably a SCUD-B copy, from a site north of Wonsan. (27:178;4:1424, 1425) In June of that year, the North Koreans reportedly agreed to sell Iran 90 to 100 SCUD-B copies, and deliveries were apparently completed in early 1988. (27:178;20:130)

North Korea is also reportedly developing a SCUD derivative with improved accuracy and range extended to 450 to 600 km. This range extension is required to satisfy North Korean targeting requirements as will be addressed in Chapter III. Development of this extended range SCUD derivative was projected to be completed in late 1989. (27:178)

North Korea's RPBM program provides an excellent example of cross-proliferation of RPBMs among the five potentially hostile regional powers in spite of bitter animosities between some pairs of powers. North Korea supplied SCUD-B copies to Iraq's enemy Iran while continuing to collaborate with Iraq's ally Egypt on RPBM development. This long-standing North Korean-Egyptian collaboration reportedly dates back to 1976 when Egypt transferred a small number of SCUD-Bs to North Korea in return for Korea's assistance to Egypt during the October 1973 war. (27:177-180)

In February 1990, Jane's Defence Weekly described North Korea as a "... 'totally uncontrollable' player in the world missile market ... " that has offered to sell additional SCUDs to at least five Middle East nations including Iran and Syria. (28:295)

Iraq: RPBM Modification and Development

The CINC USCENTCOM, General Schwarzkopf, highlighted Iraq's indigenous RPBM development capability in his statement for the Senate Appropriations Committee on March 6, 1990:

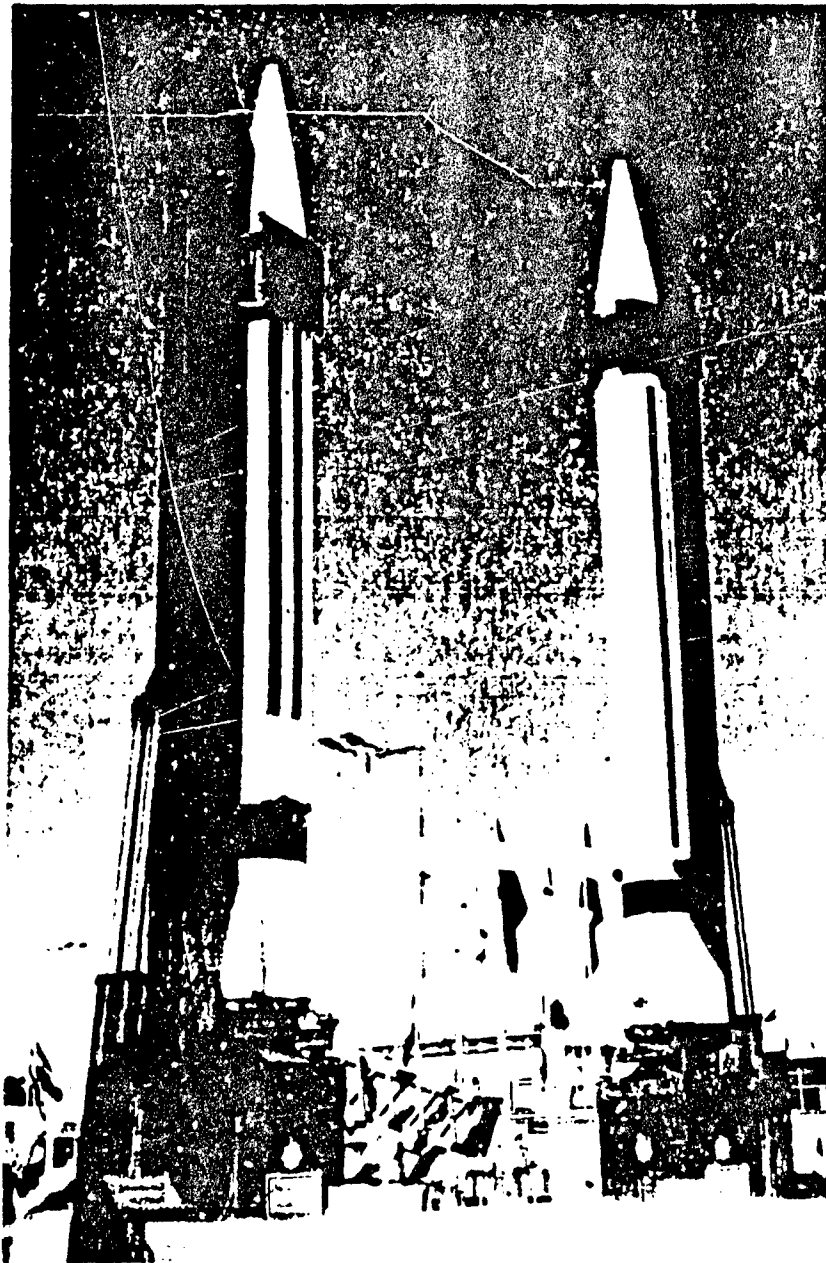
Iraq continues to import arms. Of greater concern, however, is its domestic arms industry, the most advanced in the region. Iraq is now capable of producing chemical munitions and medium-range missiles. The recent test firing of an Iraqi-developed three-stage missile with a range of over 1,500 nautical miles (2,780 km) will create a perceived need for a similar capability in neighboring states. (6:17)

Iraq developed extended range derivatives of the SCUD during the Iran-Iraq War because the Iranian capital city of Teheran, the Iraqis primary target, was over 500 km from the border and thus was beyond the 300 km range of a standard SCUD-B. When Iraq announced in August 1987 that a missile with a range of 600 km, twice the SCUD-B range, had been successfully tested, the claim was generally discounted by Western observers. However, this claim was taken seriously when the Iraqis hit

Teheran with seven missiles on February 29, 1988 at a range of approximately 530 km from the nearest Iraqi launch points. (4:1425; 7:52,53; 26:298) The increased range of this first SCUD derivative, designated the "Al Husayn", was reportedly achieved by reducing the warhead weight from 1000 kg to between 250 and 135 kg. (4:1425; 7:53; 26:298) Because of the high kinetic energy of the warhead impacting at very high speed, the missiles caused extensive damage to buildings around the impact points in Teheran even with the smaller warhead. (4:1425)

The second Iraqi SCUD derivative was a more ambitious modification that tripled the range without reducing the weight of the standard one tonne (1,000 kg) warhead. This Iraqi derivative, designated the "Al Abbas", was stated to have a range of 900 km and was reportedly successfully test fired 850 km in April 1988. (7:52; 26:298) This relatively major missile modification was facilitated by the simplicity of the basic SCUD design. This range extension was apparently achieved by increasing the rocket propellant tank capacity of the SCUD-B. (4:1425) The modification involved cannibalizing one SCUD-B, cutting the fuel and oxidizer tank sections of the cylindrical missile airframe in half, and then using those half-tank sections to increase the length of the propellant tanks of two other SCUD-Bs by 50 percent. The Iraqis were reportedly assisted by technical advisors from both North Korea and East Germany. (4:1425; 7:53) Between February and May 1988, the Iraqis fired more than 190 SCUD-Bs and SCUD derivatives, and 90 percent of them were the Al Husayn derivative. (4:1425)

A photo of these two SCUD derivatives on display at an Iraqi arms exhibition in April 1989 was featured in Soviet Military Power 1989, and that photo is reproduced as Figure 2. (17:124; 29:1374)



These Iraqi-modified Scud B ballistic missiles offer tangible evidence of the diffusion of sophisticated weaponry and weapons technology to Third World nations.

Figure 2. Extended Range SCUD Derivatives on Display in Iraq
(Soviet Military Power 1989, p 174)

Iraq's ability to triple the original range of the SCUD-B reflects both the proliferation of ballistic missile technology among the regional powers and the inherent producibility of the original Soviet design. For convenience in subsequent references in this study, the modified SCUD design with a nominal range of 900 km (Iraqi designation Al Abbas) will be referred to as the "SCUD-Extended Range" or "SCUD-ER".

Iraq's RPBH development program continued after the August 1988 cease fire in the Iran-Iraq war. In an April 1989 interview with Jane's Defence Weekly, Iraq's Lt Gen Amar Hamoudi Hassan Al-Sa'adi stated that "Regarding our missiles, we have a programme for improving their range and accuracy, also the assortment of missiles and propulsion systems. We're well on our way to achieving this." (29:1374)

In December 1989, Iraq's Minister of Military Industrialization, Hussein Kamel, formally announced both the first flight test of a satellite launch vehicle and two tests of a surface-to-surface missile with a range of 2,000 km. (30:1317) These twin advances in Iraq's missile program were so dramatic that they earned the editorial page headline of "The Iraqi Breakout" in the Wall Street Journal. (31:A14) The claimed 2,000 km range of the new "Abed" missile is more than double the 900 km range of Iraq's Al Abbas (SCUD-ER), and this new missile will dramatically enhance Iraq's target coverage. (29:1371,1374)

Mr. Kamel announced and released video coverage of what was stated to be the first test launching of a three stage, 25 m (82 ft) high booster capable of launching a satellite into orbit. This new 48 tonne missile is approximately 8 times heavier than the standard 5.9 tonne SCUD-B. (29:1371;4:1427) Press reports indicate the booster uses SCUD hardware. (32:16) The broadcast video shows that the first stage is significantly

larger in diameter than the upper stages and the rocket exhaust plume is complex. (34) These features suggest that the first stage could have a cluster of SCUD rocket engines to multiply the total thrust, a standard design approach used on numerous U.S., Soviet, French, and Chinese boosters with multiengine first stages.

This new booster is credited with the capability for ranges from the IRBM to the ICBM categories if fired on surface-to-surface trajectories instead of into orbit, but apparently only the first stage was tested in this initial launch, and no payload was orbited. (33:14; 30:1317) Based on standard missile design approximations, a booster with the propulsion performance required to achieve orbital velocity with even a lightweight satellite is also inherently capable of being fired on surface-to-surface trajectories to either ICBM range with a lightweight payload or to IRBM range (nominally 1,500 nmi or 2,780 km) with a heavier reentry vehicle substituted for the upper stage. Accordingly, General Schwarzkopf's testimony on March 6, 1990 credited the Iraqi missile with ". . . a range of over 1,500 nautical miles." [2,780 km] (6:17)

Iran: RPRM Acquisition

In addition to the SCUD copies imported from North Korea, the Iranians claimed that by April of 1988 they were also producing copies of the SCUD-B. (27:178; 20:130) As an example of the willingness of regional powers to expend RPRMs in combat, the Iranians fired 77 SCUDs during the 52 day "War of the Cities" in the Spring of 1988. As many as 5 missiles per day were fired, and up to three were launched within 30 minutes, indicating that the Iranians were operating at least three TELs. (20:130)

The Iranians did not need to develop or acquire an extended range SCUD derivative during the Iran-Iraq War because all of the key Iraqi

targets were within the standard SCUD-B range of 300 km. Nevertheless, Iranian government officials described in considerable technical detail the specific modifications the Iraqis were making for both of their longer range SCUD derivatives. (36:48; 4:1425; 20:126-130) Therefore, the Iranians and their North Korean suppliers clearly have the technical insight into the combat proven design modifications that would be required to also produce the SCUD-ER derivative if Iran's future targeting requirements demanded increased range.

Missile Proliferation From Nonhostile Regional Powers

In addition to these extensive RPBM production, modification, and development activities underway among the potentially hostile regional powers themselves, the Chinese are stimulating RPBM proliferation.

According to the DCI, Judge Webster:

China has emerged as a willing supplier, as evidenced by its sale of the CSS-2 intermediate range ballistic missile to Saudi Arabia. China is actively promoting the sale of shorter-range ballistic missiles. (1:14)

According to Jane's Defence Weekly, the CSS-2s have a range of 2,700 km, the longest range of any currently operational RPBMs, but they are relatively inaccurate. (37:744-745) The CSS-2s were originally deployed by the Chinese in 1971 and were designed to deliver heavy thermonuclear warheads with yields estimated at 1 to 3 megatons. (37:744) Therefore, the modified missiles sold to the Saudis can carry a large high explosive warhead estimated to weigh about 2.2 tonnes (2,200 kg or 4,840 lb), but the CEP is about 2 km. (26:304,305; 7:2,7,62-65) Although this limited accuracy compromises the military utility of the CSS-2s, they were the only missiles available on the international market at the time that could reach Teheran from Saudi bases to deter Iranian attacks on Saudi oil

facilities. (4:1427; 26:305) As Mr. Les Aspin, Chairman of the House Armed Services Committee, noted, "It's not a coincidence that the Saudis paid for enough range to strike every major city in Iran and Iraq." (38:15)

In the context of this study, the CSS-2s controlled by friendly Saudi Arabia are not a threat. However, Libya has reportedly also been trying to purchase CSS-2s, and any Chinese sales to potentially hostile regional powers could expand the threat to deployed US forces. (7:62)

The Director of Naval Intelligence, Rear Admiral Brooks, testified in March 1990 that China's active marketing of M-type ballistic missiles in the Middle East could result in sales to Syria, Libya, and Iran. (40:A4; 39:1385) The M-11 "SCUD substitute" can be launched from the standard SCUD-B TEL, has similar overall performance, and also uses storable liquid propellants, but the missile itself is not identical to the Soviet design. (4:1424) According to Jane's Defence Weekly, the M-9 is a technically advanced, mobile, solid propellant missile with a range estimated at 600 km. (39:1385)

Argentina: RPB Development

Argentina and Brazil, two non-hostile regional powers with relatively advanced aerospace industries, are contributors to the proliferation of RPBMs among the potentially hostile regional powers. As will be discussed below, the roles of Argentina and Brazil are significant particularly because these two regional powers have previously had access to relatively advanced Western European and American guidance and propulsion technologies for their civilian sounding rocket and space launcher programs. (7:86-95; 26:291,292) These Western missile technologies and components could be exploited to complement or upgrade

the Soviet missile technologies already available to the potentially hostile regional powers.

The DCI testified in 1989 that "Iraq hopes to acquire and eventually produce Condor-II under development in Argentina." (1:16) The Chairman of the House Armed Services Committee, Mr. Aspin, added in 1989 that Egypt was also working on Condor-II with Iraq and Argentina. (38:13) Libya is also reported to be trying to buy the Condor-II. (7:62)

Argentina has apparently been trying to develop the Condor-II since 1982, and Iraq and Egypt have reportedly been funding the program since the mid-1980s. (26:291) Argentina had previously developed a single stage, solid propellant Condor-I sounding rocket, and the Condor-II program reportedly received assistance from the European firms that had participated in that scientific rocket program. The Condor-II is reported to be a two stage, solid propellant missile which is credited by Jane's with a design range of 900 to 1,000 km with a 500 kg (1,100 lb) warhead. (28:295; 39:1384,1385; 7:86) The Condor-II design apparently includes a French inertial guidance system and Italian solid propellant technology. (7:86,87)

Even with this financial support from several regional powers and European technical assistance, the Condor-II development program apparently has not progressed as rapidly as planned, and no successful flight tests of the Condor-II had been reported by February 1990. (28:295; 39:1384,1385) The Assistant Secretary of State for Politico-Military Affairs, H. Allen Holmes, testified in May 1989 that the Condor-II program ". . . is far behind schedule . . ." because the Missile Technology Control Regime (MTCR) had slowed exports of key technology for the program. (41:852) The MTCR, which was announced in April 1987, is a

cooperative policy effort by the governments of the United States, Canada, Federal Republic of Germany, France, Italy, Japan, and the United Kingdom. The MTCR is intended to restrict the exports of technology and equipment that could contribute to the development of nuclear-capable missiles. (7:104; 41:852) According to Chairman Aspin, "... the technology control effort has made it harder for the Argentine-Egyptian-Iraqi consortium to develop a working Condor missile." (38:13)

In December 1989, Jane's Defence Weekly reported that Argentina's role in the Condor-II program had diminished while Iraq's role had increased. (29:1371,1374) Iraq's objective in continuing the Condor-II development program is apparently to assimilate the Condor-II's solid rocket propulsion technology into Iraq's indigenous RPBW production capability. (28:295) Construction of an Iraqi production plant for solid propellant missiles was completed during 1989 with European assistance, and missile production reportedly could begin within two years. (42:1) An initial test flight of a Condor-II prototype has been predicted within one to two years. (29:1374)

Although the Condor-II does not offer increased range or payload compared to Iraq's 900 km SCUD-ER, the solid propellant Condor-II could offer improved responsiveness by eliminating the liquid fueling operations required for the SCUD derivatives. This Iraqi collaboration with Argentina on the Condor-II is consistent with the statement by Iraq's Lt Gen Amar Hamoudi Hassan Al-Sa'adi that "Regarding our missiles, we have a programme for improving their range and accuracy, also the assortment of missiles and propulsion systems." (29:1374)

By February 1990, Egypt was reported by Jane's Defence Weekly to have withdrawn from the Condor-II program under pressure from the United

States. (28:295) In June 1988, the United States had charged several Egyptian civilians and senior military officers with trying to smuggle carbon-carbon ablative materials to Egypt for use in the Condor-II reentry vehicle heat shield and rocket motors. (26:291; 28:295) An Egyptian-born US citizen employed by a US military missile contractor was convicted in 1989 for that attempt to illegally export carbon-carbon. (29:1374; 28:295)

Brazil: RPBK-Related Missile Development

Brazil, like Argentina, has a relatively advanced aerospace technology base for a regional power and has several interrelated missile development programs that are contributing to the proliferation of RPBK-related technology. Brazil aggressively markets its military missile exports and does not place any "end user" restrictions on subsequent transfers of missiles among potentially hostile regional powers. (7:88,94)

With French and West German assistance, Brazil produced hundreds of the "SONDA" series of suborbital scientific sounding rockets with progressively increasing payload and altitude capability. The latest SONDA-IV version is credited with a 500 kg payload and a surface-to-surface range estimated at 625 km. (43:432; 44:15; 7:88-92) The SONDA's were two stage vehicles which gave Brazil initial experience with multi-stage design approaches required for longer range solid propellant RPBKs.

Brazil's Avibras company used the civilian SONDA rocket motor designs as the basis for the military "ASTROS-II" unguided artillery rockets which have been exported in large numbers to Iraq, Libya, and Saudi Arabia. Iraq, Brazil's best military customer, used the ASTROS-II extensively in the Iran-Iraq War. (26:293; 7:94)

Two Brazilian RPBK development programs had been highlighted in earlier missile proliferation studies. (7:89,90; 26:293) Avibras has

conducted preliminary ground tests of the rocket motor for a missile designated the SS-300 with a design range of 300 km. In addition, Avibras and the Brazilian government's Aerospace Technical Center collaborated on the design of a missile designated the SS-1000 with a nominal range of 1200 km, but development of that longer range design has apparently not been approved. (7:89,90; 26:293; 44:16) Therefore, these Brazilian programs are in much earlier stages of the development cycle than the comparable Iraqi, Chinese, North Korean, and Indian programs which have already progressed into flight test or even into production.

Brazil's most ambitious missile program is the "VLS" satellite launch vehicle being developed under the indigenous civilian "Total Brazilian Space Program". The design of the four stage, solid propellant VLS is based on technology from the SONDA rocket series. (44:15; 7:90) This large booster weighs approximately 49 tonnes. Although Brazil denies that it has military applications, the VLS could have an IRBM-class surface-to-surface range of approximately 3,000 km if equipped with a reentry vehicle. (7:90,91; 26:293) However, the VLS program has been repeatedly delayed. In March 1988, Brazil announced that the first launch had again been postponed because of MTCR restrictions. (7:90) Although a subscale prototype was launched in 1989, development of the full scale VLS has been delayed by MTCR constraints on the availability of guidance components, and the first launch is now not scheduled until 1992. (46:8)

Avibras has formally announced formation of a joint venture with China for launch of a Brazilian Earth observation satellite on a Chinese booster and collaboration in satellite and booster technologies. (45) Reportedly, the Brazilians are transferring western solid propellant technology to China in return for Chinese liquid propulsion and guidance

technologies. (7:93) This Chinese technical assistance could help Brazil's VLS booster progress into flight test. (7:90,94; 26:293)

India: RPBM Development

In May 1989, India successfully test fired an RPBM "technology demonstrator" designated the "Agni". (47:1052,1053; 46:8) The editor of Jane's Strategic Weapons Systems noted in December 1989 that ". . . the Agni is another example of the successful integration of satellite launcher and IRBM development programmes." (39:1385)

The Agni combines a solid propellant first stage from India's SLV-3 satellite booster with a liquid fuel second stage based on the "Prithvi" TBM developed for the Indian Army. (47:1052; 7:71,72) The 14 tonne missile was initially tested at a range of 1,000 km. (47:1052) The Agni has been credited with a one tonne payload and a range of 1,500 mi (2,414 km). (46:8; 7:71,72)

This Agni flight test and the Iraqi missile tests are graphic illustrations that the regional powers' RPBM development programs are continuing to progress despite the MTCR restrictions on technology transfer. The Indian RPBM program is addressed here because it provides several excellent examples of significant technical achievements by a regional power's indigenous RPBM development program. There are, however, no published reports that India has directly collaborated on RPBMs with the potentially hostile regional powers addressed in this study.

The successful Agni test flight demonstrated several design features that are potentially applicable to other regional power's RPBM development programs. First, stage separation and ignition sequencing for a vehicle with a solid propellant first stage and a liquid fuel second

stage. Second, inertial guidance with an indigenously developed "strapdown" system. Third, a reentry vehicle capable of protecting a warhead from the aerothermal stresses of reentry from a 1,000 km trajectory. As will be addressed in Chapter IV, the Indians highlight the significance of the "strapdown" guidance system with its indigenously developed software for the redundant onboard computers. (47:1052)

Missile Availability Summary

In the 300 to 600 km range class, 300 km SCUD-Bs and copies are deployed by all five of the potentially hostile regional powers. SCUD-B inventories range from tens to hundreds, and additional missiles are readily available from ongoing production in North Korea. Both the reduced warhead "Al Husayn" SCUD derivative and the aggressively marketed Chinese M-7 offer range extension to 600 km.

RPBMs in the 900 to 2000 km range class are also becoming available. Iraq has developed both the combat tested 900 km SCUD-ER and the recently tested 2,000 km Aabed. Because of the extensive cross-proliferation of RPBM technologies, SCUD derivatives in this range class will become available to any of the potentially hostile regional powers, either from their indigenous development programs or from the other regional powers. When development is completed, the Iraqi-Argentine Condor-II will provide an additional missile in this range class that should be available to any of Iraq's allies.

As will be delineated in Chapter III, an RPBM with a nominal range of 1,300 km could satisfy several specific intraregional targeting requirements of several different regional powers. Although no specific

RPBM development effort with that nominal range goal has been identified in the literature, a 1,300 km range capability would be available to the regional powers from several different RPBM development paths. For example, the 1,300 km range could be achieved by: incrementally upgrading the 900 km range of the SCUD-ER derivative by another 44 percent; increasing the range of the developmental Condor-II by a similar increment; or simply by firing the new Iraqi RPBM design at only 65 percent of its claimed 2,000 km range. Therefore, for the target accessibility assessment in Chapter III, an "RPBM-1300" with a nominal range of 1300 km has been postulated for this study.

RPBMs in the 3,000 km range class will also become available well before the year 2000. Iraq's new three stage booster will provide this range capability when development is completed. Additional development of Iraq's new Aabad design could potentially extend its range from the currently claimed 2,000 km to the 3,000 km class. The Chinese may also sell additional CSS-2s, this time to the potentially hostile regional powers. Furthermore, RPBM derivatives of the VLS satellite launcher will probably be broadly marketed by Brazil once development of that booster is completed. Again, because of the extensive cross-proliferation of RPBM technology, Iraq's longer range RPBM designs should become accessible to the other potentially hostile regional powers with significant RPBM development capability such as North Korea.

Therefore, in summary, any of the five potentially hostile regional powers could potentially develop or acquire RPBMs with ranges from 900 km to over 3,000 km well before the year 2000.

CHAPTER III

TARGET ACCESSIBILITY

This chapter addresses the second question of target accessibility: can the missiles available to the potentially hostile regional powers reach bases where US forces probably will be deployed? As was delineated in Chapter I, this study is focused primarily on the threat to US forces deployed at air bases overseas. This study does not directly address the use of RPBM in conflicts among the regional powers themselves. However, as was illustrated in Chapter I in the cases of Iraq, Iran, and Saudi Arabia, the missile range requirements for those potential intraregional conflicts dominate the RPBM acquisition or development decisions of the regional powers. Therefore, by influencing the ranges of the RPBMs that are brought into the inventories of the potentially hostile regional powers, these intraregional targeting requirements determine which deployed US forces are indeed within range for those RPBMs.

For both of the regions being considered, target accessibility by RPBMs will be graphically depicted by missile range arcs overlaid on standard regional maps. Because of the distortions introduced by the cartographic projections used for these standard maps, these depictions of missile range arcs are necessarily only approximate. For the more definitive target accessibility assessments for this study, the ranges between target bases and potential missile launch areas were determined from standard aeronautical Operational Navigation Charts (ONCs) at 1:1,000,000 scale. Because this study is a top-level assessment of the threat from RPBMs which, in some cases, are still in development, these

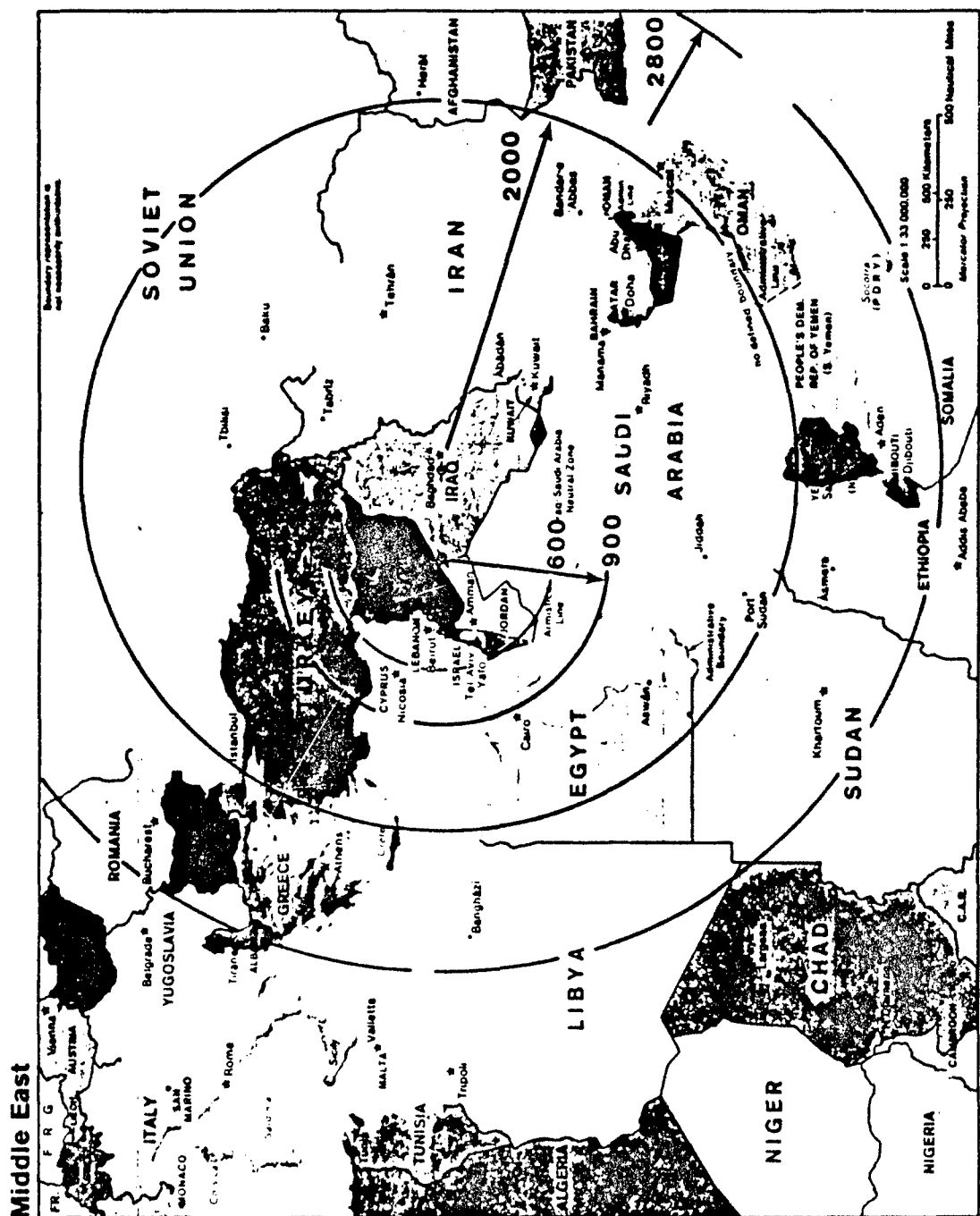
graphical range estimates were considered sufficiently accurate. Identification of deployment air bases to be considered as potential targets in the accessibility assessment was based on both the published Air Force charts of "USAF Major Installations" and the Air Force Magazine's 1989 "Air Force Almanac". (48:1-2,1-3; 49:152-161)

North Africa/Middle East/Southwest Asia Region

The four regional powers previously designated as potentially hostile in this region are Iraq, Iran, Libya, and Syria. For Iran and Iraq, the targeting requirements for their bipolar conflict were addressed in Chapter II. Therefore, this chapter will focus on their other intra-regional targeting requirements, particularly against archenemy Israel, and on their corresponding capability to target US deployment bases.

Iraq

When development of Iraq's new Aabad (designated RPBK-2000) is completed, almost all of the potential target areas in the entire Middle East will be accessible. Assuming that the Aabad achieves the claimed 2,000 km range, the potential target coverage will be as depicted in Figure 3A. In that figure, the missile range circle is centered on Iraq's Al Anbar missile development site 80 km west of Baghdad. (29:1374) With the 2,000 km Aabad, Iraq will be able to target almost all of Iran including the port and airfield at Bandar-e Abbas and sites along the Gulf of Oman. Furthermore, even from that single launch site, the Aabad could reach all of Saudi Arabia, northern Oman, most of Egypt and almost all of Turkey. If launched from southern Iraq, the Aabad could cover all of Oman. Therefore, Iraq could target any of the bases in Arab nations



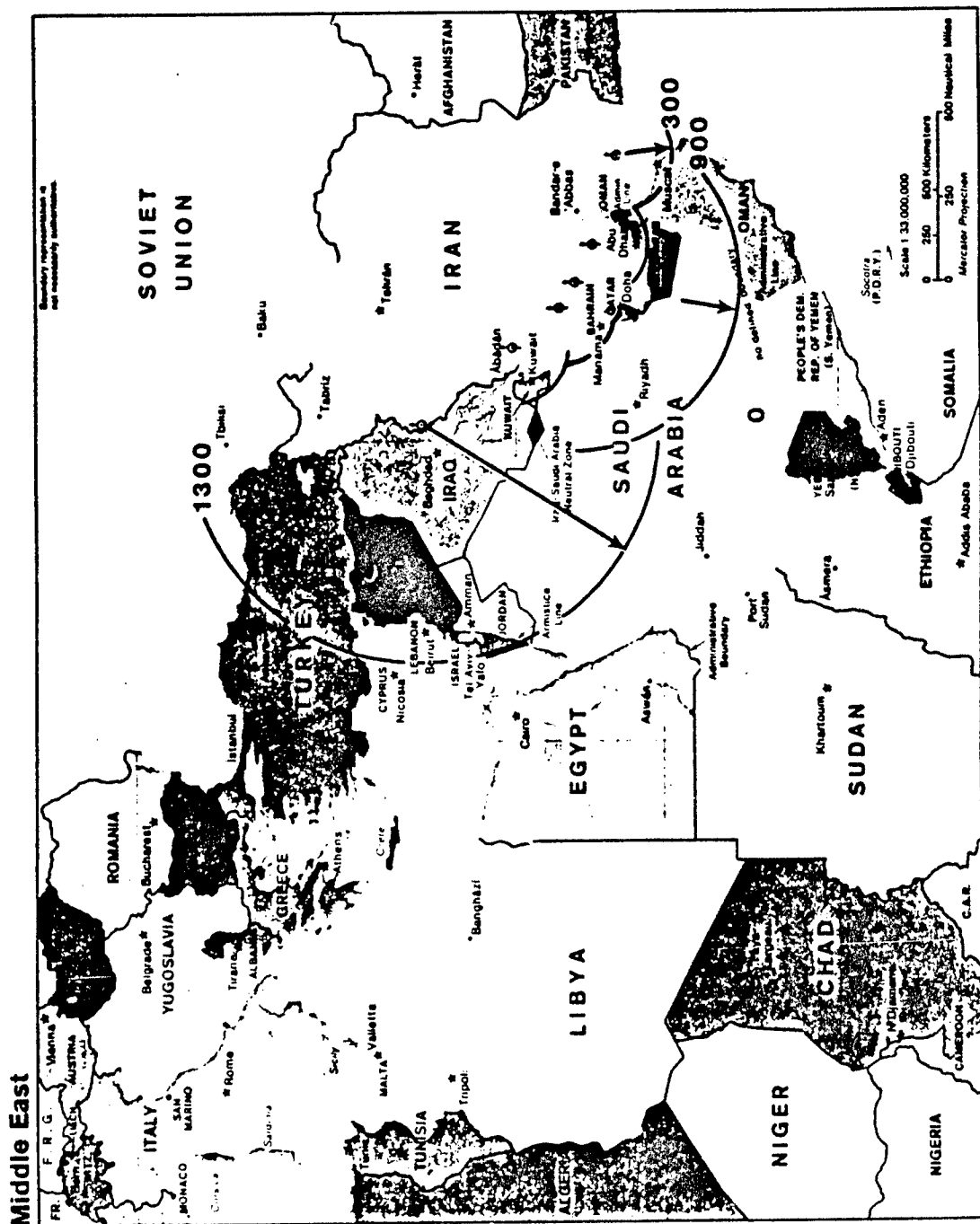
friendly to the United States that American forces might potentially deploy into for contingency operations.

The new Iraqi space booster which is credited with a surface-to-surface range of at least 2,780 km would further extend Iraq's target coverage to include Pakistan, Somalia, Greece and beyond. Even the US deployment base at Diego Garcia which is about 5,400 km from Baghdad is potentially within range of a derivative of this booster which could provide ICBM range capability as was discussed in Chapter II.

Iraq could apparently satisfy key parts of its intraregional targeting requirements with the 600 km SCUD derivative and 900 km SCUD-ER that it previously fired during the Iran-Iraq War. As is depicted in Figure 3A, SCUD-ERs launched from near the Iraqi-Jordanian border could cover all of archenemy Israel as well as the US deployment base at Incirlik, Turkey. In March 1990, published reports claimed that Iraq had constructed fixed launchers at the H-2 airfield in that area for the Al Husayn SCUD derivative. (35:A4) Because Tel Aviv is only about 430 km from the Iraqi-Jordanian border or 560 km from the H-2 site, and Incirlik is approximately 530 km from northwestern Iraq, SCUD derivatives fired at those targets would be operating within the range demonstrated repeatedly during the Iran-Iraq War.

Iran

Iran's existing SCUD-Bs can reach coastal Persian Gulf states, but RPBMs with ranges from 900 to 1,300 km are required to reach other key intraregional targets and most bases where US forces might be deployed. As is depicted in Figure 3B, the 300 km range of the standard SCUD-B is adequate to reach across the Persian Gulf to target the capitals of the



coastal Gulf states and any US Navy or Air Force units that deployed to coastal bases in a contingency.

However, the Saudi Arabian capital of Riyadh and the Saudi CSS-2 missile sites and major air bases are further inland. (37:744,745) In order to reach these key intraregional targets, the Iranians would need to acquire or develop an RPBM with the 900 km range of the SCUD-ER. As is apparent from Figure 3B, Iranian SCUD-ERs could also target any bases in northwestern Saudi Arabia or central Oman that US forces might potentially deploy into for contingency operations. Furthermore, with an RPBM in the SCUD-ER class, Iran could also target the US base at Incirlik in Turkey which is about 860 km from Iran's northwest corner.

However, the Israeli capital of Tel Aviv is over 1,010 km from the nearest section of the Iran-Iraq border and therefore is out of range for a SCUD-ER fired from Iran over Iraq to Israel. To target most of Israel from Iranian launch sites outside the tense Iran-Iraq cease-fire zone, Iran would need a missile with a range of approximately 1,300 km. Therefore, Iran would be strongly motivated to participate in development of an RPBM-1300 as postulated in Chapter II.

As was discussed in Chapter II, Iran has a well-established customer relationship with the North Korean SCUD production and range extension program. (27:177-181) Furthermore, Iran understands the modifications required to convert its SCUD-Bs to the SCUD-ER configuration. (4:1425; 36:48) Therefore, longer range RPBMs from the SCUD-ER to the postulated RPBM-1300 should become available to Iran during the early 1990s.

Syria

For Syria, as is depicted in Figure 4, the current inventory of SCUD-Bs could satisfy some of the apparent intraregional targeting goals

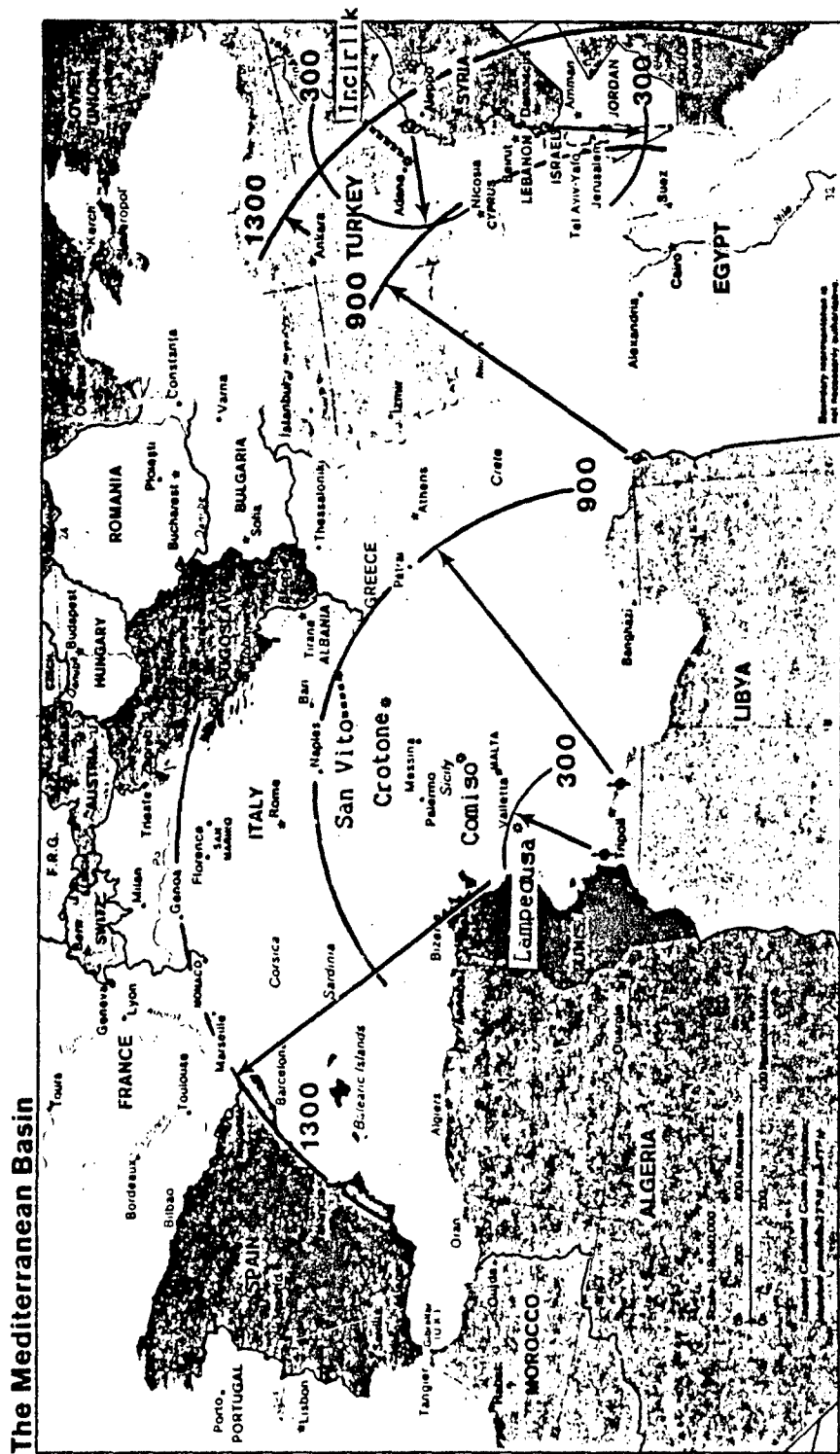


Figure 4. Target Accessibility: Libya and Syria

and could also threaten some deployed US forces. Almost all of Israel is within the 300 km SCUD-B range from potential Syrian launch points south of Damascus. Furthermore, the U.S. base at Incirlik is less than 150 km from potential launch sites in northwestern Syria near Aleppo.

However, as is apparent from Figure 3B, standard SCUD-Bs cannot threaten Baghdad, the capital of Syria's rival Iraq, which is approximately 340 km from the Syrian border. Therefore, Syria would be motivated either to collaborate with other regional powers on SCUD range extension or to acquire longer range RPBMs such as the Chinese M-type.

Libya

Intraregional targeting requirements appear to drive Libya toward developing or acquiring longer range RPBMs which could threaten several US deployment bases and allies as is depicted in Figure 4. The US Navy installation on Lampedusa Island that Libya fired SCUDs at in 1986 is about 280 km from Libyan coastal sites and therefore is at the outer limit of the standard SCUD-B's range. If the Libyan SCUDs are modified or SCUD-ERs are acquired from the regional power SCUD production and modification consortia, then several US installations could be targeted. The two air bases within range would be the cruise missile base at Comiso on Sicily (which is scheduled to be closed) and the planned new base at Crotone, Italy, which is scheduled to receive the F-16 wing being relocated from Torrejon in Spain. (49:98) Two other deployment-related facilities, the port at Naples which is frequented by US Navy forces and the Air Force installation at San Vito, are at the outer edge of the nominal SCUD-ER range envelope.

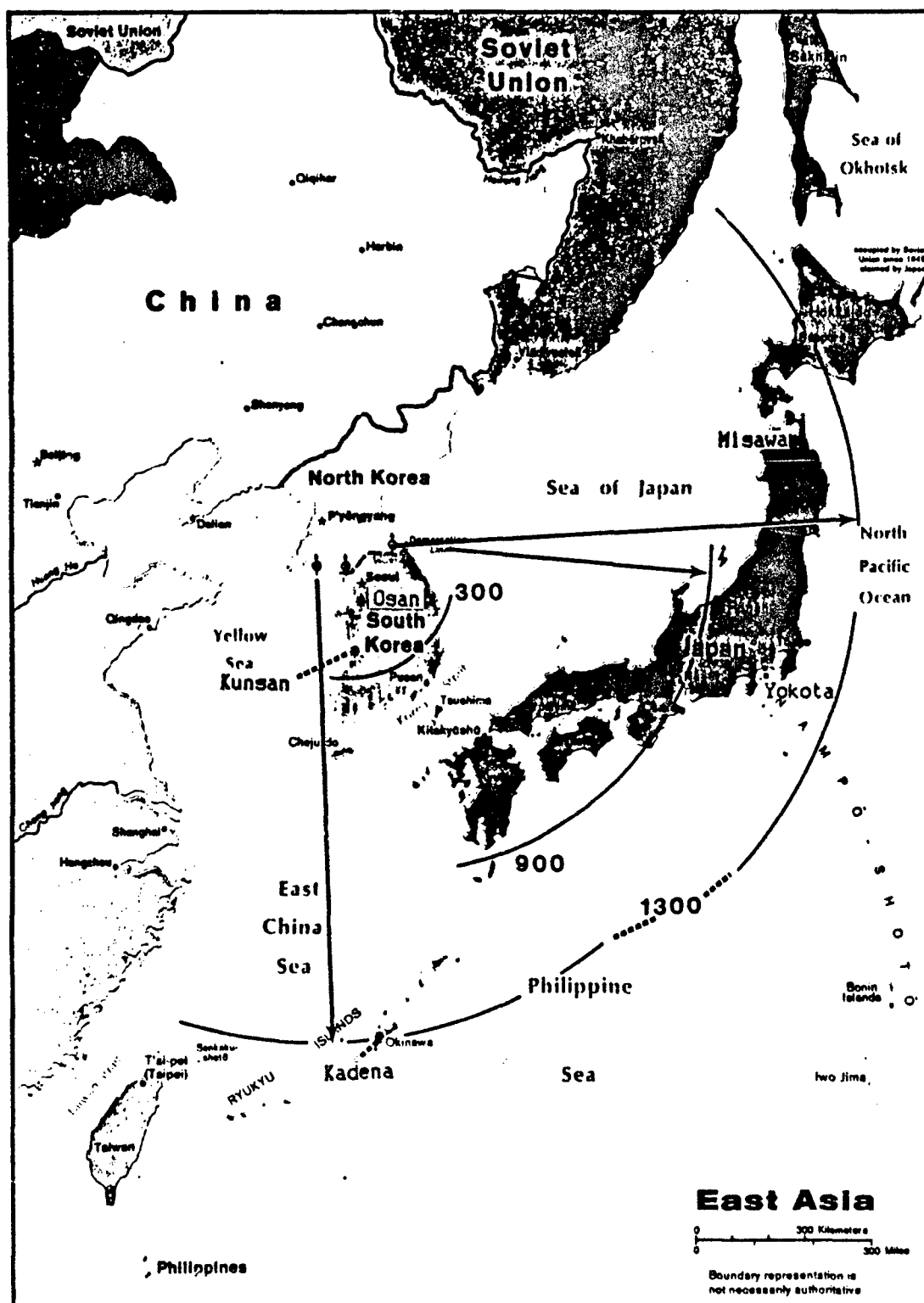
Libya, like Iran, would be motivated to acquire or participate in the development of a longer range RPBm such as the RPBm-1300 postulated in

Chapter II. As is depicted in Figure 4, SCUD-ERs could barely reach the coast of Libya's archenemy Israel even if launched from near the Libyan-Egyptian border. With an RPBM-1300 capability, Libya could target all of Israel, the US air base at Incirlik, Rome and most of the rest of Italy, and the major French and Spanish coastal cities including Marseille and Barcelona. If Libya acquires an RPBM with the 2,000 km range of Iraq's new Aabed, all of western Europe could be targeted. As is apparent from Figure 4, most bases in North Africa or the Middle East that US forces might deploy into for contingency operations could also be targeted by Libyan RPBM-2000s. As was discussed in Chapter II, Libya has previously collaborated on RPBMs with both Iran and North Korea. An RPBM capability to target US deployment bases and allies could be perceived by Libya as deterring the United States from conducting and US allies from supporting any attack on Libyan facilities such as the chemical weapons plant at Rabta.

Northeast Asia Region

North Korea

As noted in Chapter II, North Korea is reported to have an ongoing program to develop an extended range SCUD derivative to satisfy its intra-regional targeting requirements. (27:177-181) As is apparent from Figure 5, the standard SCUD-B cannot reach targets at the tip of South Korea. The two US air bases at Osan and Kunsan are well within range. However, as Bermudez and Carus delineate in Jane's Soviet Intelligence Review, South Korean bases near Kwangju, Taegu, and Pohang are at the outer limit of the SCUD-B range of 280 to 300 km, and strategic rear area targets including Pusan and Masan are out of range. (27:178,180) With the SCUD



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Figure 5. Target Accessibility: North Korea--1,300 km RPBM

range extension, North Korea could then target all bases on the peninsula that US forces might deploy into for a contingency.

In order to target deployment bases outside the Korean peninsula that US forces supporting South Korea could use, North Korea will be motivated to develop or acquire RPBMs with ranges from 1,300 to 3,200 km. As is depicted in Figure 5, the SCUD-ER with a range of 900 km could reach southern Japanese cities but could not target the US deployment bases that would be crucial for United States support to South Korea in a contingency. The three critical US air bases are Kadena on Okinawa, the primary aerial port at Yokota, and the fighter base at Misawa.

(49:154,158,161) All three of these key bases in the "inner ring" of US deployment bases could be targeted with a missile in the RPBM-1300 class. As is illustrated in Figure 6, an RPBM with a range of 3,200 km (RPBM-3200) would give North Korea the capability to target the "outer ring" of U.S. deployment bases: Andersen AFB on Guam and Clark Air Base and Subic Bay Naval Base in the Philippines. As was detailed in Chapter II, RPBMs in both of these range classes are potentially available to North Korea through collaboration among the potentially hostile regional powers and with the nonhostile regional powers.

Far East



Figure 6. Target Accessibility: North Korea--3,200 km RPBW

Target Accessibility Summary

The five potentially hostile regional powers can target several US deployment bases and can satisfy many of their intraregional targeting requirements with the SCUD-B and SCUD-ER RPBMs that have already proliferated among them. In addition, when development of the two Iraqi missiles now entering test is completed, Iraq will have the capability to target any base in the Arab world that American forces might deploy into.

To satisfy their longer range targeting requirements, Iran, Libya, and North Korea will be motivated to collaborate among themselves and with the other hostile and nonhostile regional powers to develop RPBMs in the 1,300 km range class (RPBM 1300). Proliferation of the new Iraqi 2000 km RPBM design would also satisfy this requirement. These RPBMs in the 1,300 to 2,000 km range classes will make additional US deployment base targets accessible to the potentially hostile regional powers.

In Northeast Asia, North Korea will be motivated to also acquire or develop an RPBM with a range of about 3,200 km in order to target the "outer ring" of US Pacific deployment bases on Guam and the Philippines.

CHAPTER IV

TARGETING ACCURACY FOR REGIONAL POWER BALLISTIC MISSILES

Introduction to Targeting Accuracy Assessment

This chapter addresses the study's third question of missile targeting accuracy; what is the guidance accuracy of the regional powers' ballistic missiles, and can commercial satellite data be exploited to enhance the overall missile targeting accuracy by reducing launcher and target location uncertainties?

The overall targeting accuracy with which an RPBM can deliver a warhead to the vicinity of the designated aimpoint is a combination of the accuracy limitations of the inertial guidance system of the missile itself and of the uncertainties in the locations of the missile launcher and the target. The targeting accuracy of an RPBM is as sensitive to launcher and target position errors as it is to missile guidance errors. Furthermore, both the launcher and target locations must be referenced to a common, earth-centered geodetic coordinate system, a process termed "geolocation". (50:133,134) Missile accuracy is normally stated in terms of "Circular Error Probable" or "CEP". The CEP is defined as the radius of a circle centered on the designated aimpoint within which half of the missiles fired at that aimpoint would statistically be expected to impact.

The combined effects of missile guidance accuracy limitations and the uncertainties in launcher and target location can be incorporated into an

"Effective CEP". The uncertainties in launcher and target locations can be treated as offsets to the initial and final points of the missile trajectory. Therefore, the CEP attributable to missile guidance accuracy limitations and the two radii of uncertainty of the launcher and target locations can be Root-Sum-Squared (RSSed) together into an "Effective CEP" that includes all three contributions. (51:102,103)

This assessment of RPBM targeting accuracy will follow the same logic path of first assessing the three contributions to inaccuracy and then determining the overall Effective CEP. Therefore, the next four sections will sequentially address: Missile Inertial Guidance Accuracy; Launcher Geolocation; Target Geolocation; and then Overall Targeting Accuracy (Effective CEP). Finally, the related topics of Aimpoint Selection and Damage Assessment will be briefly addressed.

Missile Inertial Guidance Accuracy

Introduction to Inertial Guidance for Regional Power Ballistic Missiles

Ballistic missile inertial guidance accuracy is the cumulative result of the accuracies of an interacting set of subsystems: the gyroscopes that maintain inertial orientation; the accelerometers that measure missile velocity changes, the missile guidance computer, the servo control subsystem that steers the missile; and the subsystem that terminates thrust when the required velocity has been achieved. The traditional inertial guidance design concept uses a precisely balanced inertial reference platform suspended on low friction gimbals and stabilized by three superbly balanced mechanical gyroscopes spinning at very high speed. (7:19,20; 52:5-3,5-7 to 5-14)

An alternative inertial guidance design concept called a "strapdown" design is gaining importance for RPBM's. In a strapdown design, the gyroscopes and accelerometers are rigidly mounted to the missile instead of being suspended on a gimballed inertial reference platform. This design approach eliminates the relatively delicate and complex gimballed platform and shifts the burden of keeping track of the inertial reference attitude to the guidance computer. (7:19,20; 52:5-18) As will be illustrated, because of the tremendous advances in computer technology since the 1960s, the computer hardware and software challenges for strapdown guidance have become easier for regional powers to overcome than the high precision mechanical fabrication and integration challenges for traditional gimballed inertial systems.

Guidance has generally been assumed to be the primary constraint on RPBM proliferation because of the challenges of the very high precision mechanical fabrication required for the traditional gimballed inertial guidance system with mechanical gyros. (7:20,21) The DCI, Judge Webster, testified in 1989 that "... most Third World nations lack the expertise to build missile guidance systems. Cutting off the supply of guidance technology can cripple a Third World missile program." (1:15)

However, the MTCR restrictions on guidance technology exports may have very limited effectiveness in constraining the RPBM development programs of the most technically advanced regional powers. As will be delineated, extensive proliferation of missile guidance technology has already occurred. Furthermore, aircraft laser gyro inertial technology that could be adapted for RPBM guidance is widely available on the international commercial market.

Three sources of RPBM inertial guidance technology for the potentially hostile regional powers will be addressed in the next three sub-sections: Guidance Technology From Soviet Tactical Ballistic Missiles; Guidance Technology From Western Powers and Nonhostile Regional Powers; and Guidance Technology From Commercial Aircraft Laser Gyro Systems.

Guidance Technology From Soviet Tactical Ballistic Missiles

Numerous assessments of Soviet TBM guidance accuracy have been published in the open literature because of the intense debate in Western defense circles over the severity of the Warsaw Pact TBM threat to NATO installations. (53:1-9) As was discussed in Chapter II, the SCUD-B and the longer-range SS-12 SCALEBOARD were "second generation" Soviet TBMs. The SCUD-B has a three gyro "simplified inertial" guidance system. (4:1426) The SCUD-B is credited with a CEP of 900 to 1000 m. (4:1427; 7:38; 51:95; 54:158) Its contemporary, the SS-12 SCALEBOARD was credited with a slightly better CEP of 730 to 750 m at a range of 900 km, three times the SCUD-B range. (4:1427; 7:38 51:95; 54:158) This SCALEBOARD accuracy at the longer range reflects a higher quality guidance system than the "simplified inertial" system of the SCUD-B. For the subsequent assessments, a representative CEP of 900 m will be attributed to these "second generation" Soviet TBMs.

The Soviet "third generation" TBMs, the SS-21, SS-23, and the upgraded SS-12B/SS-22 SCALEBOARD, which were deployed during 1977 to 1981 had significantly improved accuracy. (51:95,96) By 1978, Soviet open literature sources were discussing reducing TBM CEPs to ". . . a few hundred meters." (12:347) In 1985, Soviet Military Power stated that this ". . . new generation of shorter range missiles can be employed effectively with conventional and improved conventional munitions in light

of their greatly increased accuracy." (19:38) Referring to the upgraded version of the SCALEBOARD, Soviet Military Power 1988 stated that the ". . . modification significantly improved the accuracy while maintaining its 900 km range." (21:54) The respected Institute for Strategic Studies credited the upgraded SCALEBOARD with a CEP of 370 m. (51:95) The 500 km SS-23 is credited with a CEP of 250 to 350 m. (12:347; 51:95) The shortest range third generation TBM, the 100 km SS-21, is credited with a CEP of 280 to 300 m. (12:347; 7:40; 51:95) For comparison, the 5,000 km SS-20 which was also deployed in the late 1970s is credited by Jane's with a similar CEP of 400 m. (18:906) Therefore, for subsequent assessments, a representative CEP of 300 m is attributed to these third generation TBMs.

This third generation TBM technology was proliferated to the potentially hostile regional powers when the Soviet Union exported SS-21s to Syria in 1984. Because the SS-21 reportedly uses a strapdown inertial guidance system, this alternate guidance design approach has apparently also been proliferated. (18:128; 54:160)

According to a US State Department statement on March 27, 1990, the Soviet Union has now admitted that SS-23s were transferred to East Germany, Czechoslovakia, and Bulgaria. (55:4) Although the Soviets had previously denied proliferating any INF Treaty-constrained SS-23s, the new noncommunist governments in Eastern Europe announced in March 1990 that SS-23s had indeed been transferred with 72 in Czechoslovakia, 24 in East Germany, and even 2 in Bulgaria. (56:3, 55:4) The new East German and Czech governments have announced that their SS-23s will be destroyed or "dismantled". (55:3; 55:4) However, the turbulence in Eastern Europe appears to increase the possibility that regional powers might obtain guidance components or design data from these proliferated SS-23s.

Furthermore, East German technical assistance to the Iraqi RPBM program and other East European links to RPBM development have been reported. (4:1425) Therefore, these Soviet transfers of SS-23s may have significantly increased the probability of Soviet third generation TBM technology proliferating to the potentially hostile regional powers.

For their own "fourth generation" of TBMs, the Soviets are reported to have upgraded the guidance systems of the third generation TBMs to improve the CEPs dramatically to the 30 to 50 m range. (12:347; 51:95,96) The former U.S. Undersecretary of Defense for Research and Engineering, Dr. DeLauer, stated that these upgraded models of the SS-21, SS-12B/22, and SS-23 have CEPs on the order of 30 m. (57:67) Soviet publications suggest that such accuracies could be achieved with guidance systems combining either improved inertial guidance with in-flight updates of the missile trajectory or with terminally guided warheads. (22:1910) Based upon his interpretation of detailed photographs of the SS-12B released by the Soviet Union under terms of the INF Treaty, Loasby concluded in Jane's Soviet Intelligence Review that the SS-12B reentry vehicle indeed has "manoeuvring fins" for final guidance corrections during the terminal phase of the trajectory. (58:157,158) However, no reports of Soviet exports to regional powers of TBMs with these upgraded fourth generation guidance systems have been published.

As was detailed above, within each of the "generations" of TBMs the Soviets were reportedly able to maintain approximately the same CEP for all missiles of that generation, regardless of range. For a fixed level of inertial guidance system component accuracy, missile "dispersion" or CEP normally increases approximately linearly with range because of the cumulative effect of missile directional heading errors and the errors in

integrating missile accelerations into velocities. Therefore, for standardization in the technical literature, missile CEPs are normally quoted at two thirds of a missile's design range. (12:347) Presumably, the Soviets maintained approximately the same CEP within each generation of TBMs by incorporating higher quality inertial measurement components into the longer range missile types within each generation.

Therefore, when regional powers modify a missile design to extend the range, the guidance system must also be upgraded or the missile CEP will be degraded approximately in proportion to the range extension. For example, if a Soviet-exported or replicated SCUD-B guidance system was used without upgrading in a SCUD-ER at three times the range, the nominal 900 m (0.9 km) CEP at 300 km could degrade by a corresponding factor of three to about 2.7 km at the 900 km range of the SCUD-ER.

Guidance Technology From Western Powers and Nonhostile Regional Powers Brazil

As was discussed in Chapter II, both the nonhostile and potentially hostile regional powers have been avidly seeking Western missile guidance technology for their RPBMs. For example, the major French guidance system manufacturer SAGEM reportedly supplied inertial components for Brazilian missiles despite US and UK protests. (59:18; 7:93; 26:293) Because of the extensive cross-proliferation of RPBm technologies among both potentially hostile and nonhostile regional powers, key guidance technologies could be rapidly incorporated into several RPBMs once the technologies became accessible to any one of the regional powers.

The Brazilian company AVIBRAS and China's Great Wall Industry Corporation have established a missile-related joint venture called INSCOM. According to AVIBRAS's technical marketing literature, the

collaboration includes satellite launch vehicles, launch services and ground stations. (60:1-4) The Brazilians are also reported to be seeking Chinese guidance technology through this joint venture. (7:93; 26:293)

In addition, the AVIBRAS technical marketing publications highlight the company's indigenous capability to produce and test a family of strapdown inertial guidance systems. (61:2,4) However, apparently the performance levels of those systems are currently only adequate for very short range tactical missiles.

India

The successful flight test of the strapdown inertial guidance system on India's new Agni IRBM appears to establish an important precedent for the future development of RPBM guidance systems. (47:1052,1053) The indigenously developed strapdown inertial system uses an on-board computer with twin redundant processors for missile guidance and flight control. (47:1052) In addition, the computer conducts the prelaunch checkout of the entire missile system. The Indians proudly and publicly highlight the successful indigenous development of the flight software as a major technical achievement for a regional power. (47:1052) Other regional powers are likely to follow this successful Indian precedent because of the increasing availability of flight qualified versions of commercial computers and software expertise and the proliferation of strapdown laser gyro inertial systems as will be addressed next.

Guidance Technology From Commercial Aircraft Laser Gyro Systems

Instead of acquiring guidance technology specifically designed for missiles from the Soviets, Western powers, or other regional powers, another alternative is to adapt commercially available aircraft inertial navigation systems for missile guidance. The 1988 Congressional Research

Service (CRS) report on missile proliferation states that "The inertial components now in use in both military and commercial aircraft navigation systems are accurate enough for many missile applications." (7:21) This CRS report also notes that "In the past France, China, the Soviet Union, the United States and Great Britain have adapted aircraft navigation systems for use in their military missiles." (5:21) For example, the Delco Electronics "Carousel IV" Inertial Navigation System (INS) which was procured beginning in the late 1960s as the USAF standard INS for all strategic airlift and tanker aircraft was also used as an upgraded guidance system for the Air Force family of Titan II ICBMs and Titan III space boosters. (52:6-7; 62:259) As an example of the extent of aircraft INS proliferation, over 7,000 Carousel IV systems have been produced, and they are in service with 60 airlines around the world. (62:259)

While acknowledging the accuracy of current aircraft inertial systems, the 1988 Congressional Research Service report repeats a long-standing but now questionable caveat that aircraft inertial systems may not be applicable to missiles because of the higher acceleration and vibration levels encountered during missile launch. (7:21) This caveat was appropriate for the relatively delicate conventional inertial systems with high speed mechanical gyros and accelerometers balanced on precision gimbal assemblies. However, this caveat has now been overtaken by the new technology of strapdown Ring Laser Gyro (RLG) inertial systems.

Ring laser gyros are inherently rugged, and a strapdown inertial system using RLGs can be designed with no mechanical moving parts. A laser gyro is inherently rugged and stable because the sensing element is a single block of glass with two laser light beams propagating in opposite directions inside it around a closed optical path or "ring". In a

strapdown inertial system, three of these RLGs are typically combined with solid-state accelerometers and a digital computer. It is the synergistic combination of the small, flight qualified digital computers to analytically maintain the inertial reference attitude and the RLGs that has made these advanced strapdown inertial systems feasible.

Published performance specifications for current aircraft RLG inertial systems illustrate their tolerance for high accelerations and severe vibrations. For example, a typical RLG inertial system by Ferranti of the United Kingdom is designed for linear accelerations of 12 g, and a Litton RLG INS is designed to maintain full specification accuracy under gunfire shock and severe random vibration of 7.9 g and to endure 17.9 g. (62:246; 63:2) Furthermore, these rugged RLG INSs have very long life (7,000 hours) and can be inertially aligned in from 30 seconds to 10 minutes. (62:264,266)

Furthermore, the navigation accuracy of current aircraft RLG systems now exceeds the accuracy of the finest mechanical gyro aircraft INSs. One convenient but approximate figure of merit for comparing inertial system performance is the "drift rate" or accumulated position error which is usually expressed in nautical miles per hour (nmi/hr). This convenient figure of merit is widely quoted in the literature and is available in published specifications although in missile applications the errors in measuring accelerations may be more significant because of the relatively short flight time and higher acceleration of ballistic missiles. (7:19,20) In the 1960s and early 1970s era of the Carousel IVs (which were adapted for Titan missile guidance as discussed above), the standard aircraft INS drift rate specification was 2 nmi/hr, and conventional INSs in production in the early 1980s had improved to 1 nmi/hr. (62:263,273) By 1985, RLG

INS performance had surpassed conventional systems and an RLG system was selected as the Air Force's new standard aircraft INS with a drift rate specification of 0.8 nmi/hr. (62:263,266,274) In practice, RLG INS performance was even better, and a drift rate of 0.24 nmi/hr CEP was demonstrated in an F-15 with an RLG of the Honeywell 700 series that has been adapted for missile guidance as will be highlighted below. (62:266)

Because of these desirable characteristics, RLG inertial systems have been selected for several U.S. mobile ballistic missile systems, both ground-launched and air-launched. The Army Tactical Missile System (ATACMS), a mobile TBM credited with a range of over 100 km which has now entered production, uses a Honeywell inertial system based on the same 700 series RLG as their standard aircraft INS discussed above. (64:72; 62:266) Similarly, the Air Force Short Range Attack Missile-2 (SRAM-2) strategic air-launched ballistic missile and its planned tactical variant, SRAM-T, use a Litton RLG inertial system based on their aircraft RLG INS technology. (63:4; 65:31,32) Demonstrating that RLG inertial systems are applicable to ballistic missiles with up to ICBM range, a high accuracy RLG Alternate Inertial Navigation System (AINS) was developed for the US land-mobile Small ICBM ("Midgetman") and was flight tested on a Minuteman ICBM. (18:25,26; 66:1-4)

Aircraft RLG INS technology and hardware is broadly commercially available worldwide. Thousands of RLG INSs are being installed worldwide in commercial transport aircraft including the 747, 757, 767 and A-300 series, usually in triple redundant sets. Furthermore, simplified, lower cost RLG INSs produced specifically for the worldwide corporate and general aviation aircraft markets now have drift rate specifications of 2 nmi/hr, equal to the world's best aircraft inertial systems of the 1960s

and early 1970s. (62:264,265) In addition, British and French avionics manufacturers are producing RLG INSs with drift specifications better than 1 nmi/hr for both civil and military aircraft, and the Japanese have also entered the RLG INS market. (62:236,237,243,246: 63:6) Both Ferranti of the United Kingdom and SPENA of France also produce very high accuracy RLG inertial systems for the European Space Agency Ariane heavy-lift booster. (62:237)

Because of the increasing number of international sources and the very large numbers of RLG INSs in service and in spares stocks, diversion of aircraft RLG INS hardware for use in RPBM guidance systems appears to be both feasible and highly probable.

Summary of Missile Inertial Guidance Accuracy Assessment

As is apparent from the detailed discussion above, the topic of RPBM inertial guidance accuracy is quite complex. Several different types of RPBMs are already deployed, and RPBMs currently in development range from SCUD derivatives to new missile designs. Furthermore, several different sources of guidance technology are already or potentially available to the potentially hostile regional powers: Soviet second generation (SCUD-B and SS-12) and third generation (SS-12R, SS-21 and SS-23) missile guidance; western and nonhostile regional power guidance technology; and aircraft laser gyro technology adapted for missile guidance. New guidance technologies retrofitted into existing missiles can improve accuracy whereas range extension generally degrades accuracy unless compensating guidance upgrades are also introduced. Furthermore, the regional powers themselves would need multiple test firings to experimentally determine with reasonable confidence the actual accuracies of new or modified RPBMs.

Therefore, for the missile warhead effectiveness assessment in the next chapter, three different levels of potential RPBM accuracy will be considered. These three levels will be designated as "nominal", "optimistic", and "pessimistic". These designations are from the perspective of the potentially hostile regional power; the improved accuracy (smaller CEP) corresponding to the "optimistic" accuracy increases the effectiveness of the RPBMs.

For the "nominal" accuracy level, a CEP of 900 m will be invoked. This accuracy level is based on the assumption that Soviet second generation guidance technology is upgraded moderately with some Soviet third generation or western guidance technology in order to maintain the accuracy attributed to the Soviet second generation missiles (900 m CEP at 900 km) out to the extended RPBM ranges (1,300 to 3,200 km). Invoking this 900 m CEP for RPBMs by the mid-1990s, thirty years after the Soviets deployed TBMs credited with that accuracy, appears to be a reasonably conservative assumption for "nominal" accuracy.

For the "optimistic" accuracy level, a CEP of 300 m will be invoked. This accuracy level is based on the assumption that regional powers will exploit newer Western guidance technologies such as the laser gyro inertial systems or will acquire Soviet third generation (SS-21 and SS-23) guidance in order to achieve the accuracies attributed to the Soviet third generation missiles (300 m CEP at 900 km) over the RPBM ranges. Invoking this "optimistic" 300 m CEP by the late 1990s, twenty years after the Soviets deployed missiles credited with that accuracy, appears reasonable. Proliferation of Soviet third generation and aircraft RLG INS technologies discussed above could potentially give the RPBMs of the most technically advanced regional powers this "optimistic" accuracy earlier in the 1990s.

For the "pessimistic" accuracy level, a CEP of 3.6 km will be invoked. This accuracy level is based on the assumption of Soviet second generation SCUD-B simplified inertial technology (credited with 900 m CEP at 300 km) without any technology enhancements and degraded approximately linearly by the factor of four range extension from 300 to about 1200 km.

Launcher Geolocation

As was discussed at the beginning of this chapter, accurate determination of the position of the missile launcher in the same earth-centered geodetic coordinate system as the target is a crucial element of the overall targeting accuracy. For mobile RPBMs such as SCUDs, launcher geolocation is a particular challenge. Furthermore, at the launch location, the missile guidance system must be accurately aligned with that geodetic coordinate system. As the SCUD article in Jane's Weapon Systems notes, "A fairly lengthy survey procedure is also entailed on arrival at the firing position, and both tripod-mounted theodolites and optical devices attached to the missile/launcher by special brackets are employed for this." (18:127)

One straightforward approach to mobile launcher geolocation is to establish multiple presurveyed launch locations that the RPBM TELs could deploy to for missile firing. For regional powers with well surveyed national territories and the corresponding numerous geodetic survey reference markers, this presurveying approach is adequate. For example, traditional ground and aerial surveying techniques anchored to a modern geodetic coordinate system can provide feature locations to within approximately 12 meters. (67:4,5) The standard US Geological Survey (USGS) quad maps at 1:24,000 scale are examples of this surveying accuracy

class. A location uncertainty of 12 m for a presurveyed launcher site is only 4 percent of even the smallest "optimistic" CEP of 300 m and, therefore, would be a negligible contribution to the overall targeting accuracy.

For regional powers whose national territories are not well surveyed or to enhance the flexibility of mobile RPBMs, commercially available radio navigation satellite data could be exploited for launcher geolocation. Data from either the Soviet GLONASS navigation satellites or the US Global Positioning System (GPS) satellites could potentially be used, but this assessment will focus on GPS because of the availability of data on receivers and positioning accuracy. (68:37-43; 69:57,58)

Under the US "open use" policy announced by President Reagan in late 1983 after the USSR shot down Korean Air Lines Flight 007, the Coarse/Acquisition (C/A) signals from GPS satellites are available for civil aircraft navigation and other civilian uses. (69:59) This open use policy applies only to the "C/A code" signals and not to the encoded "P code" signals that are available to US and allied military users for higher precision navigation. (69:59; 68:37-43) However, even the "low precision" C/A signals provide two dimensional position determination accuracy of 40 m CEP (which corresponds to the commonly quoted "100 m" in two standard deviations RMS terms).

This GPS geolocation accuracy is fully adequate for RPBM launcher geolocation. The 40 m CEP contribution from GPS positioning uncertainty would degrade the overall RPBM accuracy by less than one percent even for the most stressing case of the "optimistic" 300 m missile accuracy. In addition, GPS receivers normally output position data in a standard, worldwide geodetic coordinate system, the World Geodetic System (WGS)

which is linked to the standard Universal Transverse Mercator (UTM) navigation chart coordinates. Many GPS receivers can also calculate position based on other major regional grid systems. (68:43)

Civilian GPS receivers are routinely commercially available for both airborne and terrestrial applications. Airborne GPS navigation sets designed to receive the C/A code are in volume production by US, French, and UK avionics manufacturers. (62:234,250,272) These receivers designed for the moderate dynamics and vibration levels of aircraft installations could be readily adapted for RPBMs. Furthermore, hand-held GPS "microreceivers" are now available on the retail commercial market for only \$3,500.00. (70:77) This GPS microreceiver by Magellan Systems has an advertised positioning accuracy of 25 m (RMS) and includes 47 different regional geodetic map datums. (70:77) Although these single channel receivers are only designed for low dynamics applications, they would be fully adequate for positioning a parked TEL. The microreceivers are approved for export to the Soviet Union and most other nations except Libya, North Korea, and Iran. (69:58)

Therefore, in summary, launcher geolocation accuracy is not a significant constraint on overall RPBm targeting accuracy because either standard geodetic mapping data (for well surveyed regional powers) or available civilian GPS receivers can provide adequate positioning data.

Target Geolocation

This section addresses the question of the accuracy with which the targets for RPBMs can be geolocated. In this study, the primary focus is on potential RPBm targeting of deployment air bases, with secondary emphasis on targeting of storage areas and anchorages for deployed US

forces. Because these are all large, fixed installations, the challenge is generally one of accurately locating the appropriate aimpoint within the overall facility. As was discussed previously, the aimpoint location accuracy must be consistent with the inertial guidance accuracy of the RPBM, and the aimpoint location must be specified in the same geodetic coordinate system as the launcher location.

The inaccuracy in target geolocation because of inadequate mapping and inconsistent regional mapping coordinate grid systems is a potentially major challenge for RPBM targeteers because many Third World areas have never been accurately mapped. In many regions, the historical evolution of mapping grid systems has been chaotic, and several of the 45 major regional mapping grid systems or hundreds of local grids may overlap. (68:43) Mapping grid inconsistencies are a particular problem if the missile launcher and target are not on the same land mass, as is the case for several of the targeting scenarios addressed in Chapter III. Errors in the charted positions of islands are particularly infamous in the history of navigation. While errors in island positions of hundreds of meters to kilometers are not critical for aeronautical navigation because of terminal radio nav aids, such errors are critical for RPBM targeting.

A pertinent example of mapping grid chaos is the area between Libya and the island of Lampedusa in the Mediterranean. Four different mapping coordinate grids overlap inconsistently in this area according to the standard Operational Navigation Chart (ONC). (71) Furthermore, these grids are based on two different geodetic reference systems, one of which, the "Clark 1880 Spheroid", is over a century old. These disconnects in the geodetic coordinate grids may have been contributing factors when the

Libyan SCUD-Bs fired at the island in 1986 missed the US Navy facility by about a mile. (1:16; 4:1427)

If detailed and accurate maps of a US deployment base areas are available to potentially hostile regional powers, geolocation uncertainties are easily resolved. For example, maps equaling the standard USGS 1:24,000 scale quad maps are available for a few well charted regions. Such maps can provide feature location data accurate to approximately 12 m which, as was discussed earlier, is fully adequate for RPBM targeting. (67:4,5) However, less than 18 percent of the mapped surface of the earth is charted to that scale. (67:4) There is an alternative approach if personnel supporting the potentially hostile regional powers have access to areas on or adjacent to the U.S. deployment bases. In that case, either conventional surveying techniques or the hand-held GPS microreceivers discussed in the previous section could be used to accurately locate reference points for aimpoint offsets. (70:77)

The French "SPOT" Earth observation satellite can also provide accurate geolocation data which reportedly could be used for RPBM targeting. (15:14) Recent editions of the US Department of Defense's Soviet Military Power have used numerous SPOT images to depict Soviet military facilities. (21:35,40, 52,60,84,143) The SPOT system was developed for and is operated by the French government space agency, CNES. Processed images are marketed commercially by SPOT Image of France through a US subsidiary, SPOT Image Corporation of Reston, VA. SPOT Image publishes detailed technical marketing data on the characteristics and capabilities of the SPOT system and highlights specific applications of the imagery such as geolocation. (72:1-4; 73:1-2; 74:1,3)

Current French plans should insure that SPOT data are available continuously during the period through the year 2000 which is addressed in this study. The initial SPOT 1 satellite which was launched in February 1986 was still operational when the replacement SPOT 2 was launched in January 1990. (76:26) According to the CNES Director-General, the launch of another direct replacement satellite, SPOT 3, is scheduled for early 1993, and launch of an upgraded version, SPOT 4, is scheduled for 1996, thus insuring satellite coverage through the year 2000. (77:4,29)

The French "open and nondiscriminatory" policy for SPOT Image distribution is that imaging services for any area of the world are available on a commercial basis to all customers. (78:7; 75:1,2,7; 79:1,20) In addition to the French mission control center which programs the satellites, SPOT Image operates an expanding global network of direct readout stations which can receive images whenever a satellite is within a 2500 km radius. (72:2; 78:7) A station is operational in Pakistan, and additional stations are being established in the regional powers China, India, Israel, Saudi Arabia, Argentina, and Brazil. (80:8; 75:8) Thus, SPOT images will be available to potentially hostile powers either direct from France or through collaboration with nonhostile regional powers.

Both Iran and Iraq reportedly have experience using SPOT images to support their operations during the Iran-Iraq War. (81:24,25; 82:50)

The technical data published by SPOT Image states that geolocation accuracies ranging from 300 m to better than 30 m can be achieved. The primary factors affecting the geolocation accuracy are satellite viewing angle, degree of digital image processing, and availability of ground reference points to "anchor" the image position. Geolocation accuracy of 200 to 300 m can be achieved even if no Geodetic Control Points (GCPs) of

accurately known location are available. (80:2) According to SPOT Image, "These figures are based on testing hundreds of SPOT scenes in all types of terrain." (80:2) The SPOT 2 satellite that is now operational includes a high precision orbit determination system specifically to improve geodetic measurements, and therefore these quoted accuracies should improve once SPOT 2 scenes are similarly analyzed. (76:26)

Geolocation accuracy can be significantly improved if the positions of one or more features within a 60 by 60 km SPOT scene are accurately known. When using only satellite data, the primary contribution to the location uncertainty is potential offset of the overall image, because internal location accuracy within a scene is better than 60 m. (80:2) Commercial image processing and interpretation firms are now routinely combining SPOT image data with ground data on Geodetic Control Points (GCPs) accurately located using GPS navigation satellites. (75:7) SPOT Image states that accuracies of better than 30 m can be attained with a few accurately located GCPs within the image area, and examples of geolocation accuracy of better than 15 m have been published. (83:2; 80:4,5; 75:7) Therefore, if personnel supporting the potentially hostile regional powers have access to areas near US deployment bases, either conventional surveying techniques or GPS microreceivers could be used to accurately locate GCPs and "anchor" SPOT images for use in RPBM targeting.

As a test case for both SPOT Image's "open and nondiscriminatory" policy and SPOT's geolocation accuracy, a commercial image analysis firm purchased a scene of France's Albion Plateau and used the image to locate the 18 French IRBM silos. (84:20-23) According to Kennedy and Marshall of Grayscale Inc., "The data on the frame would be adequate for targeting. In as little as two hours an analyst using manual methods could plot each

of the 18 positions accurately within 50 meters. Geocoding the image could produce more accuracy, but would take more time . . ." (84:22)

These geolocation accuracies attainable using SPOT images would be fully adequate for targeting RPBMs with the inertial guidance accuracies invoked in this study. For example, for an RPBm with the "nominal" 900 m CEP, the conservative SPOT 1 geolocation accuracy of 300 m (using only satellite data) would degrade the overall targeting accuracy by only about 5 percent. For the "optimistic" RPBm guidance accuracy of 300 m CEP, this SPOT 1 "space only" geolocation accuracy of 300 m would degrade the overall accuracy by about 41 percent. Therefore, for the more accurate RPBMs, the additional effort required to anchor SPOT data to GCPs to achieve an accuracy of about 30 m would be worthwhile. This would reduce the geolocation uncertainty contribution to the overall targeting error to less than one percent.

For the more accurate RPBMs where aimpoint selection is meaningful, SPOT images apparently could also be used to identify specific aimpoints within US deployment bases. For example, the SPOT Image technical marketing publication Surveillance features interpretive analysis of enlarged areas of a SPOT image of an air base. In addition to delineating the runway, taxiway, and ramp areas, two heavy transport aircraft parked on the ramp are highlighted. Hangars, fuel storage tanks, and warehouses are also identified on the enlarged images. (85:2,3) Similarly, SPOT Image's publication Environmental Monitoring features an enlargement of an image of Iran's Kharg Island oil terminal which clearly depicts the oil storage tanks and a grounded and damaged tanker. Blackened tanks are highlighted as apparently damaged by fire and clearly distinguishable from the apparently undamaged tanks. (86:6)

Targeting Accuracy Summary

Because of the uncertainty in assessing the inertial guidance accuracies achievable with different types of RPBMs, three levels of potential inertial guidance accuracy were carried forward from the first section. As was detailed in the next two sections, the potentially hostile regional powers could exploit several sources of geolocation data to accurately establish the positions of both RPBM launchers and targets. These sources include: accurate geodetic map data (where available); GPS navigation satellite positioning data; and SPOT commercial satellite images. Geolocation data from these sources could reduce the uncertainties in the locations of both RPBM launchers and targets to negligible levels compared to the inertial guidance accuracies invoked in this study. Thus, for the approximate purposes of this study, the three inertial guidance accuracy levels will be assumed to be representative of the overall targeting accuracy including the minor contributions from launcher and target geolocation uncertainty. Therefore, three overall targeting accuracy levels will be carried forward into the assessment of warhead effectiveness: "nominal" (900 m CEP); "optimistic" (300 m); and "pessimistic" (3.6 km).

CHAPTER V

MISSILE WARHEAD EFFECTIVENESS

Introduction

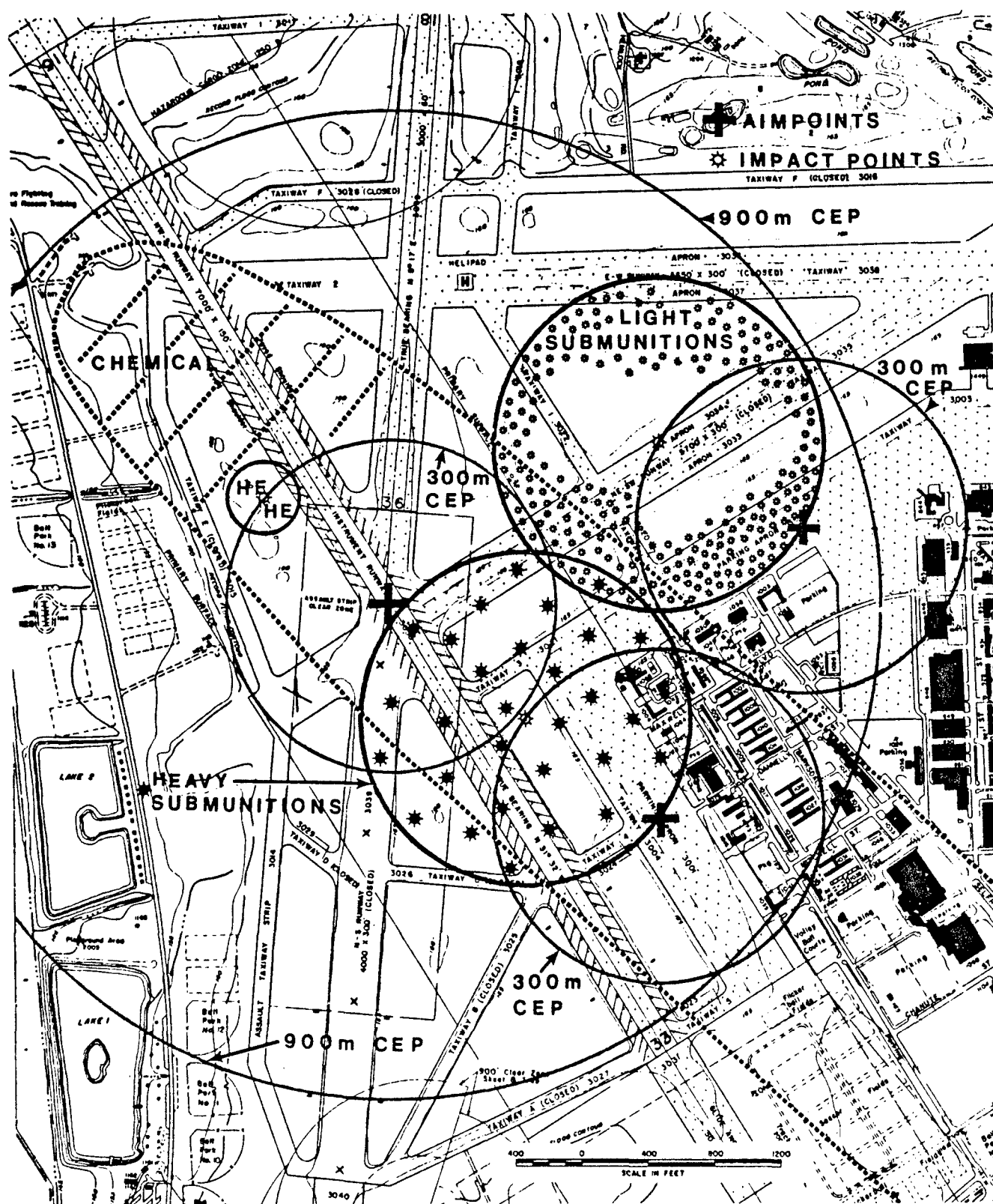
In the context of this study, RPBM "effectiveness" has a broader interpretation than the conventional interpretation of "effectiveness" as a capability to inflict substantial hardware damage and casualties upon deployed US forces. An RPBM capability to destroy large numbers of strategic airlift or combat aircraft at a deployment air base would certainly constitute "effectiveness". In addition, a more limited capability to disrupt or delay US deployment into or contingency operations out of a deployment base could still constitute "effectiveness" from the perspective of a potentially hostile regional power if that limited RPBM capability precluded effective US intervention. Even a very limited RPBM capability which could deter the United States from intervening in a regional crisis because of a perceived RPBM capability to inflict politically unacceptable losses if US forces were deployed could constitute "effectiveness" to a potentially hostile regional power.

Another factor that must be taken into account in this effectiveness assessment is that many of the deployment bases considered in this study are unhardened facilities that previously have been "sanctuaries" from attack in conventional contingency scenarios. Former Secretary of Defense Carlucci highlighted this issue (in the US/Soviet context) in his January 1989 Report to Congress which stated that "One key asymmetry unfavorable

to the United States is the Pacific Theater target base . . . US targets for Soviet attack are few in number, lightly-defended, and vulnerable." (87:23) This distinction that many US deployment bases are unhardened facilities is important because the most prominent published assessments of TBM warhead effectiveness have been for European scenarios where NATO air bases are assumed to be extensively hardened with aircraft shelters and dispersed, hardened support facilities. (16:8-12) In contrast, major deployments into most of the bases considered in this study would probably result in air base ramp areas crowded "wingtip to wingtip" with airlift and combat aircraft and large quantities of supplies and equipment crowded into unhardened storage areas.

This assessment of RPBM warhead effectiveness will use Maxwell AFB, Alabama, as a generic air base example in order to avoid the base-specific details and potential sensitivities of focusing on effectiveness against specific US deployment bases overseas. This base has a representative array of runways and ramp areas plus hangars and storage facilities. Furthermore, most US Air Force officers and many officers from other services who attended the Air University schools are familiar with Maxwell AFB. To graphically illustrate the potential effectiveness of different types of warheads, missile CEP rings and effective destructive areas of the warheads will be overlaid on a standard map of Maxwell AFB. (Figure 7)

A wide range of RPBM warhead technologies is available to the potentially hostile regional powers from both Soviet and western sources as will be detailed in subsequent sections. As was chronicled in the annual editions of Soviet Military Power, the Soviets developed and deployed a broad range of TBM warhead options including enhanced blast



high explosive, improved conventional munition (submunitions), fuel-air explosive, chemical and nuclear. (17:67; 22:1909-1914)

Four types of RPBM warheads will be addressed: high explosive; chemical; submunition; and nuclear. The order in which these warhead options are addressed corresponds both to the relative confidence that the potentially hostile regional powers have or will acquire those warhead types and to the probable temporal order of availability of warhead types.

High Explosive Warheads

The standard warhead for the Soviet export version of the SCUD-B RPBM was a single (unitary) high explosive warhead weighing one tonne (1,000 kg or 2,200 lb). (4:1426) For this effectiveness assessment, this SCUD-B warhead is assumed to be representative. As was discussed in Chapter II, some extended-range SCUD-B derivatives have smaller warheads, and the Chinese-exported CSS-2 has a warhead about twice as heavy.

For estimating the warhead blast damage radius, an explosive yield equivalent to 1,000 kg of the World War II era explosives TNT or RDX will be assumed. This assumption is appropriate because, although the weight of the explosive charge in a typical RPBM warhead will probably be lower, the RPBM explosive will probably have higher explosive yield per unit weight than TNT. For example, according to data on the SCUD-B chemical warhead released by the Soviets, the weight of the chemical agent filling is 56 percent of the overall warhead assembly weight of 985 kg. (21:77) The compensating factor is that modern "enhanced blast" explosives containing metal powders (similar to high performance solid rocket propellants) have two to five times higher blast yield per unit weight than traditional explosives such as TNT. (88:299; 22:1911) Brazil and

probably other regional powers as well as the major powers produce these enhanced blast explosives. (7:23; 18:727,728)

An RPBM High Explosive (HE) warhead with a blast yield equivalent to 1,000 kg of TNT would seriously damage vehicles or buildings of standard construction out to a radius of approximately 60 m (197 ft). (51:97,98; 7:23) This estimate is based on a blast damage criterion of 5 pounds per square inch (psi) overpressure. However, as is depicted in Figure 7, this destructive radius of 60 m is only 20 percent of the 300 m CEP invoked for RPBMs with "optimistic" accuracy. Therefore, the destructive area for an individual HE warhead covers only a few percent of the total area over which impacting warheads would be randomly dispersed. [Note that, by definition, 50 percent of the arriving warheads would be expected to impact inside the CEP circle.]

A 1,000 kg HE warhead could severely crater a runway or ramp area and disrupt aircraft operations until the debris was cleared and the crater filled. (51:113-119) However, the probability that a warhead aimed at the runway centerline would indeed impact the runway is only a few percent even for the "optimistic" 300 m CEP, and extremely small for the "nominal" 900 m CEP. (51:116-118) Warheads impacting crowded ramp areas, hangars, or storage facilities would cause severe local damage, but, as is apparent from Figure 7, only the "optimistic" 300 m CEP with an aimpoint in the ramp area would provide a reasonable expectation of damaging those areas.

Therefore, the effectiveness of RPBMs with HE warheads against US deployment bases is quite limited. Only the "optimistic" 300 m CEP provides any reasonable expectation of damaging designated aimpoints.

In addition, there is a potential indirect or "political coercion" dimension of RPBM effectiveness that could be a significant issue for

deployment bases except, perhaps, Andersen AFB on US territory in Guam. For deployment bases in allied nations, threatened or actual RPBM firings against cities of the host nation could generate political pressure for the host nation to curtail US operations at deployment bases. The Iran-Iraq war demonstrated that, even with poor accuracy, RPBMs with HE warheads are effective terror weapons against cities.

Chemical Warheads

As was noted in Chapter I, the specter of chemical warheads delivered by RPBMs has been highlighted in the public statements of senior US government officials. In his January 1990 Congressional testimony, the DCI, Judge Webster, cited the rising potential for chemical, biological and nuclear warfare among developing nations and used Iran, Iraq and Libya as examples. (3:11) Referring to the Iran-Iraq War in his March 1990 Congressional statement, USCINCCENTCOM, General Schwarzkopf, noted that "The War demonstrated growing acceptance by both sides of the use of chemical munitions as anti-personnel weapons." (6:35)

Three issues must be addressed in assessing RPBM chemical warheads: first, chemical agent availability to the potentially hostile regional powers; second, chemical warhead design availability for delivering those agents; and, third, chemical warhead effectiveness against US deployment bases for the RPBM accuracies invoked in this study.

Chemical Agent Availability

All five of the potentially hostile regional powers addressed in this study have inventories of extremely lethal chemical agents according to public statements by senior US government officials. General Schwarzkopf's March 1990 statement noted that "Iraq is now capable of

producing chemical munitions . . ." and "Iraq now has a sizable stockpile of chemical munitions." (6:17,35) The General also stated that "Iran has continued its arms race with Iraq, including advancements in the areas of chemical weapons." (6:15) The United States has formally accused Libya of building a chemical weapons plant at Rabta, and on March 8, 1990, the White House press secretary, Marlin Fitzwater, stated that Libya had renewed production of chemical weapons, posing ". . . a major threat." (89:1A,10A) The DCI stated in 1989 that Libya's Rabta plant might be ". . . the single largest chemical-warfare-agent production plant in the third world." but that Iraq has several production sites and its ". . . total production capacity . . ." exceeds Libya's. (90:8) The Chairman of the House Armed Services Committee stated that Syria has chemical warheads for its RPBMs. (38:13) North Korea is probably also producing and stockpiling lethal chemical weapons according to statements by both the former Army Chief of Staff, General Wickam and the Director of Naval Intelligence, Rear Admiral Brooks. (7:80; 92:302)

The chemical weapons inventories of the potentially hostile regional powers reportedly include extremely toxic nerve agents such as the "G-series" as well as older agents such as mustard gas. In March 1990, a West German federal prosecutor filed charges against a company accused of aiding construction of Libya's Rabta plant and declared that the plant was ". . . especially designed and solely intended for the production of the chemical weapons substances Sarin [GB], Soman [GA] and Lost." (91:A12) [G-series chemical agent designations added (7:33)] Iraq is reportedly producing the nerve agents Sarin and Tabun as well as mustard gas. (90:8) On April 2, 1990, Iraq's President Saddam Hussein declared that Iraq also has advanced "dual chemical" weapons. (93:1) Presumably, he was referring

to what are usually termed "binary" chemical weapons containing two separate liquids which are nonlethal until they are mixed after weapon launch and react to form nerve agents such as Sarin [GB]. (93:6)

Chemical Warhead Design Availability

A Soviet chemical warhead design for the SCUD-B RPBW is available to the potentially hostile regional powers, and the design is so simple that the warhead could be easily replicated. (21:77) The Soviets displayed the warhead and technical data on the design when representatives of the United States and 44 other nations participating in chemical weapons negotiations visited the Shiknany chemical weapons research and development center in October 1987. (21:77) A photo of this warhead and technical data display which was featured in Soviet Military Power 1988 is reproduced as Figure 8. The warhead weighs 985 kg (2,167 lb), and it contains 555 kg (1,221 lb) of thickened VX nerve agent. The warhead has a conical outer shell fabricated from steel and aluminum, a Radio Frequency (RF) proximity fuse at the nose, and an axial bursting charge. According to the Soviet data, the bursting charge disperses the thickened VX into "coarse aerosol and droplets" at the optimum altitude above the target. (4:1426: 21:77)

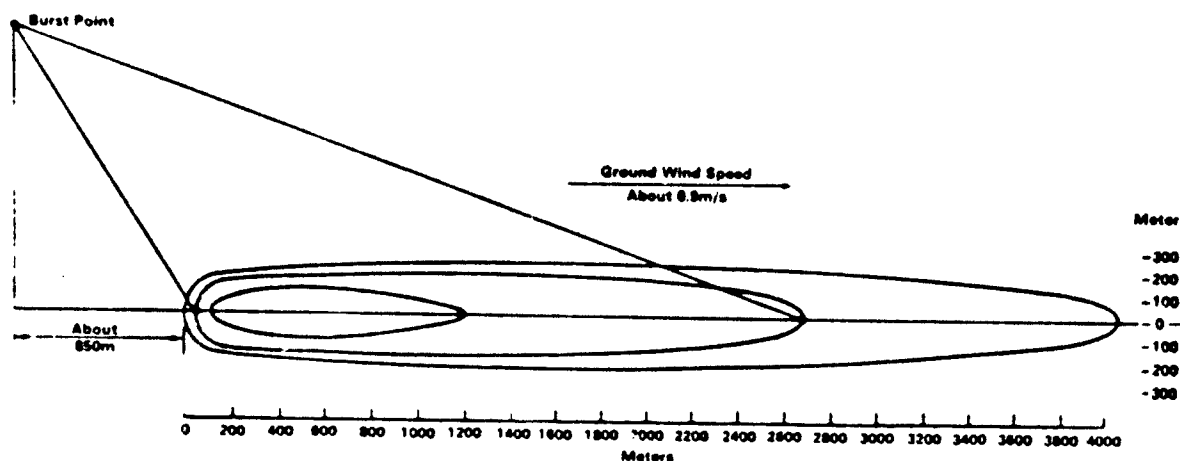
This SCUD chemical warhead design could be adapted for other RPBWs. Components such as RF proximity fuses designed to fit either Soviet or Western rocket warheads are now readily available as is apparent from advertisements in publications such as International Defense Review. (94:5) For longer range RPBWs, an external layer of ablative heat shield could be added to protect the warhead shell from the aerothermal heating during higher velocity reentry from longer range trajectories.

Chemical warheads have indeed proliferated to the potentially hostile regional powers. The Chairman of the House Armed Services Committee, Les Aspin, stated that "Let's marry, for example, a chemical warhead to a Syrian missile. This is not speculative--it's being done, albeit with a SCUD, which is a fairly primitive missile." (38:13) Jane's Soviet Intelligence Review reports that North Korean has also developed chemical warheads for the SCUD-B copies it produces and exports and that North Korea has assisted Iran in developing chemical warheads. (27:177,181) Considering the size of Iraq's chemical weapon effort highlighted above, the scope of Iraq's RPBM program and the extent of RPBM cross-proliferation among regional powers as was addressed in Chapter II, it is reasonable to assume that chemical warheads will be available to all of the potentially hostile regional powers well before the year 2000.

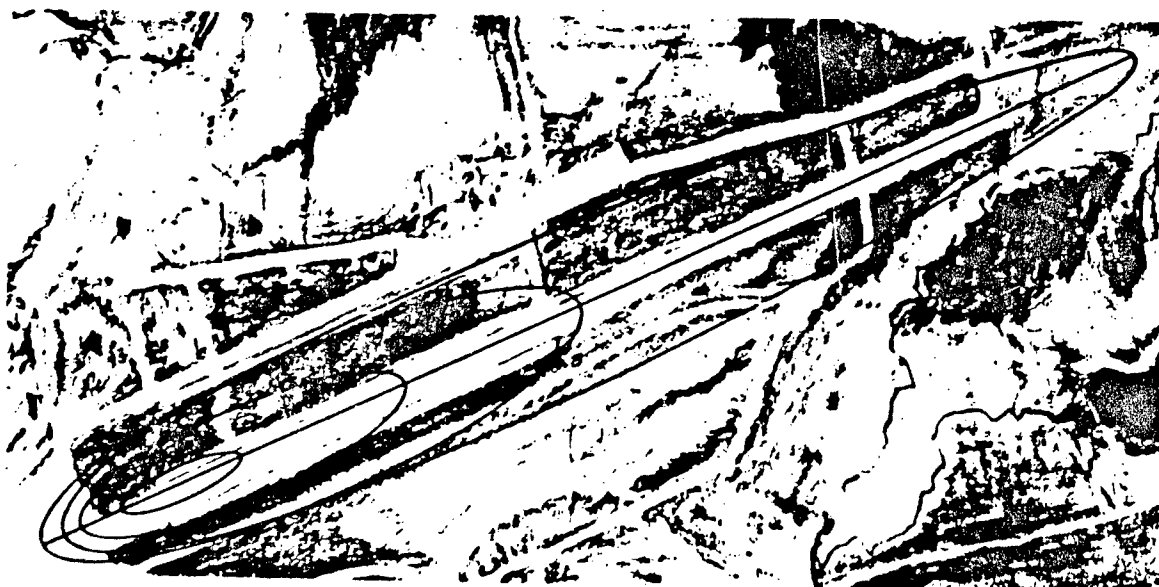
Chemical Warhead Effectiveness

Chemical warheads on RPBMs could be highly effective against US deployment air bases or other deployment facilities. The extensive ground contamination pattern that a single SCUD chemical warhead could deposit on a generic air base is depicted in Figure 9. This illustration is from the Defense Intelligence Agency (DIA) unclassified 1985 report on the Soviet Chemical Weapons Thrust, and it was featured in Soviet Military Power 1986. (95:8; 96:74) The elliptical contamination pattern is 4 km (2.5 mi) long and over 450 m (1,475 ft or 0.28 mi) wide. In this example, the contamination pattern covers the entire runway and taxiway complex, and the DIA report states that "All unprotected personnel in the area will be casualties." (95:8)

This SCUD chemical warhead contamination pattern is shown superimposed on the generic Maxwell AFB example in Figure 7. The



Typical ground contamination pattern created by a chemical warfare agent delivered by the SCUD missile. All unprotected personnel in the area will be casualties.



The SCUD-B ground contamination pattern superimposed on a military airbase runway. Operational flights from contaminated runways are extremely hazardous and difficult. The Soviets would attack a NATO airbase with many SCUD missiles to ensure coverage.

Figure 9. SCUD Chemical Warhead Contamination Pattern

(Defense Intelligence Agency)

contamination pattern is large enough relative to the "nominal" and "optimistic" CEPs that there would be a high probability of contaminating vulnerable operating areas of the base for RPBMs with those accuracies. The 4000 m length of the contamination pattern is over 4 times the "nominal" CEP, and the 450 m pattern width is 1.5 times the "optimistic" or half of the "nominal" CEP. However, for the "pessimistic" 3.6 km CEP, the CEP and the length of the contamination pattern are comparable, but the pattern width is only one eighth of the CEP. Therefore, multiple launches of RPBMs with "pessimistic" accuracy would be required to provide reasonable damage expectancy even with chemical warheads.

Because the chemical warhead contamination pattern orientation and aspect ratio vary with wind direction and speed, data on the approximate wind conditions at the target are needed to optimize target coverage by appropriately offsetting the RBPM aimpoint. Appropriate data on prevailing air base winds and current meteorological conditions are generally available through normal civil aviation channels. For reference, the contamination pattern depicted in Figure 9 corresponds to a light breeze of 0.9 m/sec (2 mph) along the runway. (95:8)

A attack by RPBMs with warheads filled with persistent chemical agents could immobilize a US deployment base for hours to days. The DIA report states that "Operational flights from contaminated runways are extremely hazardous and difficult . . ." and ". . . persistent agents will stay on target for hours to days, depending on weather conditions, unless removed by decontamination." (18:727; 4:1426) According to Jane's Weapon Systems, the thickened VX filling in the Soviet SCUD warhead is a persistent agent which is used to ". . . disable unprotected personnel through unprotected areas of the skin and to contaminate engineering

structures, terrain, and material/vehicles." (18:727) The nominal time required for VX to kill unprotected personnel is 4 to 10 minutes, and this agent persists for 3 to 21 days at 20 degrees C. Other nerve agents that potentially hostile regional powers are producing such as Soman and Sarin are quicker-acting but less persistent. (18:727)

Therefore, RPBMs with chemical warheads could be highly effective against US deployment bases for RPBM accuracies in the "nominal" to "optimistic" range (900 to 300 m CEP). Because of the large downwind contamination pattern, multiple RPBM firings could put a deployment base at risk even for the "pessimistic" RPBM accuracy (3.6 km CEP).

Submunition Warheads

Submunition warheads can partially compensate for RPBM accuracy limitations by increasing the effective destructive area of the warhead. As will be illustrated, all of the key technologies required for these submunition warheads (which are also called "improved conventional munitions") are available to the potentially hostile regional powers.

The Soviet Union developed and deployed submunition warheads for its second and third generation TBMs. Soviet emphasis in the open literature on the potential advantages of submunition warheads for TBMs dates back to a book published by Marshal of Artillery Kazakov in 1969. (22:1911,1912) As was noted in Chapter II, the Soviets developed a SCUD-C variant specifically to more accurately deliver submunition warheads. (4:1426) For the third generation SS-21, SS-23, and modernized SS-12B, the 1985 edition of Soviet Military Power stated that "The new generation of shorter range missiles can be employed effectively with conventional and improved conventional munition warheads in light of their greatly

increased accuracy. (19:38) At least the design concepts and perhaps the detailed designs of the submunition warheads for the SCUD and the SS-21 were presumably disclosed to regional power personnel being trained by the Soviets on those two exported missile systems.

Warheads With a Moderate Number of "Heavy" Submunitions

The initial Soviet publications on submunition warheads for TBMs presented design concepts for warheads with a moderate number of relatively heavy submunitions. (12:347; 22:1911) For example, the illustration from Marshal Kazakov's 1968 book depicts a single layer of sub-projectiles or "ammunition elements" which are closely packed across the base of the warhead assembly. The overall configuration of the warhead closely resembles the SCUD chemical warhead design discussed in the previous section, and the "ammunition elements" have the ogive/cylinder configuration of Soviet artillery rocket warheads or shells. (18:77) Marshal Kazakov presents two design examples for 1000 kg warheads: one with 100 sub-projectiles of about 10 kg each; and another with 40 sub-projectiles of about 25 kg each. (12:347; 22:1911,1912) As Hines and Bellamy detail, these sub-projectiles are analogous to standard Soviet artillery rocket warheads. (12:348;22:1912) For example, the Soviet high explosive fragmentation warhead for the 122 mm artillery rocket weighs 18.4 kg. (18:727) The Soviets exported 122 mm rockets to all five potentially hostile regional powers, and copies are in production in Egypt and North Korea. (18:702,728; 54:152) Therefore, the 122 mm rocket warhead will be used as the "heavy" submunition example.

An RPBM submunition warhead design analogous to the SCUD chemical warhead design could accommodate approximately 30 "heavy" submunitions in the 122 mm rocket warhead class. This estimate is based on the assumption

that the weight of the warhead structure, proximity fuse, and dispersing charge would be about the same as for the chemical warhead and that the 555 kg payload weight could be allocated to 30 of the 18.4 kg warheads instead of chemical agent. (4:1426; 18:77; 12:348; 22:1912) The conventional approximation that submunitions should be dispersed over a radius equal to the missile CEP has been adopted. (51:104,105)

For this example of a warhead with 30 "heavy" submunitions dispersed over a radius equal to the "optimistic" 300 m CEP, a submunition would impact approximately every 110 m (359 ft). For reference, this 110 m average spacing between impacting warheads is 2.2 times the 49 m (160 ft) wingspan of C-141 strategic airlift aircraft that would probably be on the ramp at most deployment air bases. The destructive zone around each impacting 122 mm warhead ranges from 14 m (47 ft) for personnel to 6 m for equipment. (54:116; 18:727; 97:212) As a result, the destructive zones from adjacent impacting submunitions do not overlap for this relatively sparse submunition dispersal pattern. Therefore, increasing the submunition dispersal radius for RPBMs with larger CEPs would not be feasible.

As is depicted in Figure 7, a few of the "heavy" submunitions from typical arriving warheads would be expected to impact vulnerable areas of a generic air base for the "optimistic" 300 m CEP. Quantitatively, for the case of an aimpoint in the center of the 50 m (164 ft) wide runway, only 2 of the 30 submunitions would be expected to impact the runway on the average. (51:119,121) For an aimpoint in the middle of the 122 m (400 ft) wide aircraft parking apron, approximately 5 submunitions would be expected to impact along the ramp area. (51:117,121; 98:74,78,79)

Combat experience from rocket attacks on air bases and storage areas during the Vietnam War demonstrated that a few tens or even a few 122 mm rocket warheads could be highly destructive against unsheltered aircraft and unhardened fuel and munitions storage areas. For example, one 40 rocket attack on Da Nang destroyed 5 aircraft and damaged 25, and another 56 rocket attack on that base damaged 13 aircraft and killed or wounded 135 US personnel. (97:44,45,174,175) As an extreme example of secondary damage on a ramp area crowded with fueled and armed aircraft, a single explosion at Bien Hoa propagated and destroyed 14 aircraft and damaged another 30. (97:68) The 122 mm rocket warheads were also very effective at destroying fuel and munitions storage areas by triggering fires and secondary explosions. (97:35,36,44,45,164,174,194)

For comparison, a single RPBM with 30 "heavy" submunitions could deliver more 122 mm rocket warheads than were fired in a typical Vietnam War rocket attack salvo. Because of the limited number of launchers, the Vietnam rocket salvos normally included fewer than 18 rockets, and salvos of 36 rockets were very rare. (97:42,43)

Warheads With a Large Number of "Light" Submunition "Bomblets"

Another design alternative for a submunition warhead is the "cluster bomb" design concept with a large number of relatively small (hand grenade size) submunitions. Against "soft" area targets such as unsheltered aircraft on a ramp or fuel and supply storage areas, warheads with many "light" submunitions can relatively uniformly cover a larger destructive area than warheads with the "heavy" submunitions discussed above.

Soviet publications since 1979 have discussed TBM warheads with "light" or "bomblet" submunitions as well as designs with the "heavy" submunitions. (22:1911) Detailed data on older Soviet bomblets in the 2.5

kg weight class have been published in Jane's Soviet Intelligence Review, and less detailed data on newer Soviet submunitions in the sub-kilogram weight class have also been presented. (99:185-187)

Warheads with "light" submunitions are used on the US LANCE and Army Tactical Missile System (ATACMS) tactical ballistic missiles and on the Multiple Launch Rocket System (MLRS) artillery rockets. The LANCE warhead which is also the "Block I" warhead for ATACMS contains 1000 M-74 Anti-Personnel/Anti-Material (APAM) bomblets. (18:708) The 154 kg MLRS warhead contains 644 newer M-77 bomblets weighing 0.23 kg each. (18:707) Both the M-77 and the older M-74 are dual-purpose bomblets with a shaped charge capable of penetrating light armor and a blast-fragmentation effectiveness similar to a hand grenade. (18:133,707,709) The LANCE TBM was deployed beginning in 1972 to five NATO allies and Israel, and the M-74 bomblets in the LANCE warhead are now a relatively old and widely disseminated technology. (18:131) The LANCE warhead is reportedly designed to dispense its 1,000 M-74 bomblets over a 300 m diameter circle or an 800 m long ellipse. (54:120)

The technology for warheads with "light" submunition bomblets has indeed proliferated to the regional powers. For example, Brazil is actively exporting without restrictions the ASTROS II artillery rocket system with an optional submunition warhead with anti-tank/anti-personnel bomblets. (100:1675;7:94) Brazil's AVIBRAS prominently advertises the ASTROS II rockets as "combat proven" based on the extensive use by Iraq during the Iran-Iraq War, and the ASTROS II has also been exported to Libya. (100:1675; 18:113,114,710)

An RPBM warhead in the 1,000 kg class could accommodate between 1000 and 2000 submunition bomblets. This estimate is based on design analogies

with the released details of the SCUD-B chemical warhead design. The 555 kg payload allocation in the SCUD warhead could accommodate 1,000 of the 0.5 kg bomblets or 2,000 of the 0.25 kg bomblets with a 10 percent allowance for packaging. Published design concepts for packaging and dispensing submunitions are straightforward: the MLRS submunitions are simply nestled in polyurethane foam; and cluster munitions such as the Rockeye use linear shaped charges to cut open the warhead shell to allow the bomblets to disperse in the airstream. (18:707,756) As was discussed for the chemical warhead design, all of the technologies required such as the RF proximity fuse to initiate submunition dispersal at the proper altitude are available to the potentially hostile regional powers.

For the effectiveness assessment, an RPBM warhead with 1,000 submunitions dispersed over a radius equal to the "optimistic" RPBM CEP of 300 m will be assumed. Under these assumptions, a submunition would impact approximately every 19 m (62 ft) within the dispersal pattern. This 19 m typical spacing between submunitions corresponds to an average of 2.6 bomblets exploding along the 49 m (160 ft) wingspan of a C-141 or an average of 3.6 bomblets impacting across the 68 m (223 ft) wingspan of a C-5. Therefore, this submunition density would provide a reasonable probability of damaging any large aircraft caught within the 600 m (1,969 ft) diameter submunition dispersal pattern.

Potential submunition dispersal patterns are depicted on the generic air base example in Figure 7. For comparison with the "heavy" submunition case, for an aimpoint on the centerline of the 50 m (164 ft) wide runway, approximately 65 of 1,000 bomblets would be expected to impact the runway for the "optimistic" 300 m RPBM CEP. (51:117,121; 98:74) However, 0.5 kg bomblets are too small to damage a runway although aircraft on the runways

or taxiways could be damaged. Therefore, RPBMs armed with "light" submunitions probably would be targeted against "soft" area targets such as aircraft parking aprons and supply storage areas. For an aimpoint in the middle of the 122 m (400 ft) wide parking apron as depicted in Figure 7, about 160 submunitions would be expected to impact along the apron. (51:117,121: 98:74,78,79) Such a pattern of 0.5 kg (1.1 lb) bomblets could potentially inflict substantial damage on a parking apron area crowded with unsheltered deployed aircraft. Therefore a "light" submunition warhead on an RPBM with "optimistic" accuracy could be highly effective.

However an RPBM with "nominal" accuracy would not provide reasonable confidence of inflicting significant damage even with a "light" submunition warhead. As is apparent from Figure 7, for the 900 m CEP there is only a small chance that a vulnerable area of the generic air base will fall within a 300 m submunition dispersal radius. However, increasing the dispersal radius to 900 m to match the "nominal" RPBM CEP would increase the average spacing between submunitions to about 57 m (187 ft). This impact pattern would be so sparse that even large aircraft would have a reasonable chance of escaping damage in areas between impacting bomblets.

Nuclear Warheads

The DCI, Judge Webster, testified in January, 1990 that four of the regional powers developing ballistic missiles already have or are close to acquiring nuclear weapons capability and, "By the end of the decade, four more countries could be added to the nuclear list." (2:30) However, no official estimates of the expected range of explosive yields and weights

of these projected regional power nuclear weapons have been published in the open literature. Furthermore, this nuclear warhead alternative is the most speculative and longest-term of any of the warhead options addressed in this study. Therefore, only a very brief assessment will be presented. This assessment will address the question of what nuclear warhead yields would be required to produce blast damage areas consistent with the three levels of potential RPBM accuracy invoked in this study.

The basic data required for this very approximate assessment of RPBM warhead yield requirements is available from The Effects of Nuclear Weapons. This classic open literature reference has been published jointly through three editions by the Department of Defense and the Department of Energy (the Atomic Energy Commission for initial editions). (101:1) For historical reference, the fission weapons dropped on Hiroshima and Nagasaki in 1945 weighed approximately 4,500 kg and had yields of about 12.5 and 22 kilotons (kt), respectively. (101:36) Subsequent advances in nuclear weapons design dramatically increased the yield-to-weight ratio and provided yields from the sub-kiloton range to megatons as is chronicled by Glasstone.

The yields attributed to the SCUD-B warheads can be used as a point of departure in assessing what yields are consistent with RPBM accuracies and warhead weights. The Soviet nuclear warhead options for the SCUD-B reportedly range in yield from about 5 kt to 80 kt. (4:1426) However, relatively primitive regional power warheads might have significantly lower yield-to-weight ratios than even the relatively old Soviet warhead designs for the early 1960s vintage SCUDs. Therefore, RPBM warhead yields ranging from 1 to 5 kt will be considered using the blast effects scaling relationships presented by Glasstone. (101:108, 112-115)

An RPBM warhead yield of 5 kt would provide high confidence of inflicting heavy damage on a deployment base for either the "optimistic" or "nominal" RPBM CEPs of 300 or 900 m, respectively. For a 5 kt yield, blast overpressures of 6 psi and 4 psi would extend out past the 0.9 km "nominal" CEP to radii of about 1 km and 1.4 km, respectively. (101:108, 114,115) Atmospheric nuclear tests demonstrated that an overpressure of 6 psi would destroy steel frame hangars and severely damage fuel storage tanks, 5 psi would severely damage and overturn vehicles, and even 3 psi would destroy self-framing metal storage buildings. (101:170,171,176,177, 190,192,228) The nominal criterion presented by Glasstone for "severe" (unflyable) damage to parked aircraft is 3 psi overpressure, but this criterion was based primarily on tests of World War II-era aircraft designed for lower dynamic pressure than current jet aircraft. (101:194, 195,226) Fires ignited by thermal radiation from the nuclear fireball and by blast-driven debris would, of course, add to the overpressure blast damage to a deployment base.

An RPBM warhead yield as low as 1 kt would provide reasonable confidence of severely damaging a deployment base with the "optimistic" accuracy, and this low yield would have moderate effectiveness for the "nominal" accuracy. For this 1 kt yield, the blast overpressure would exceed 6 psi out to 0.6 km which is twice the "optimistic" 0.3 km CEP. An overpressure of 4 psi would extend out to 0.8 km which almost matches the 0.9 km "nominal" CEP.

However, for the "pessimistic" CEP of 3.6 km, a warhead yield of approximately 20 kt would be required to inflict even "light to moderate" building structural damage out to a radius comparable to the CEP. This level of blast damage corresponds to an overpressure of approximately 2

psl. (101:108,115) Therefore, even with nuclear warheads, there is a high payoff for improving RPBM accuracy unless the potentially hostile regional powers acquire warheads with yields in the 20 kt class or higher.

CHAPTER VI

CONCLUSIONS

This analytical study addressed the issue of whether the proliferation of ballistic missiles among potentially hostile regional powers poses an emerging threat to US forces deployed overseas. Five regional powers have been identified as potentially hostile: Iran, Iraq, Libya, Syria, and North Korea. To assess this threat, four key questions have been addressed sequentially: missile availability; target accessibility; targeting accuracy; and warhead effectiveness.

On the missile availability question, ballistic missile technology has proliferated so extensively that any of the five potentially hostile regional powers could develop or acquire Regional Power Ballistic Missiles (RPBMs) with ranges from 900 km to over 3,000 km well before the year 2000. The indigenous Iraqi program to develop RPBMs with ranges of 2,000 km and beyond and the North Korean production of copies of the Soviet SCUD-B are particularly significant contributions to RPBM proliferation.

In terms of target accessibility, the potentially hostile regional powers can target several US deployment bases and can satisfy many of their interregional targeting requirements with the SCUD-B and extended range SCUD derivatives that have already proliferated among them. When development of the two missiles now entering test is completed, Iraq will have the capability to target any base in the Arab world where US forces might deploy. In addition, to satisfy their longer range targeting requirements, Iran, Libya and North Korea will be motivated to collaborate

among themselves and with other regional powers to acquire or develop RPBM's with ranges from the 1,300 km class up to 3,200 km. These longer range RPBM's will make additional US deployment bases accessible targets.

For the targeting accuracy question, missile guidance accuracy is the key uncertainty, and the uncertainties in RPBM launcher and target locations can be made negligible in comparison. The regional powers could very accurately establish the positions of both RPBM launchers and targets by exploiting several sources of geolocation data: accurate geodetic maps (where available); GPS navigation satellite positioning data; and SPOT commercial satellite images. However, because of the uncertainty in assessing the inertial guidance accuracies achievable with RPBM's, three potential levels of guidance accuracy were invoked: "nominal" (900 m CEP); "optimistic" (300 m CEP); and "pessimistic" (3.6 km CEP). These accuracy levels were based on analogies with the accuracies attributed to the second and third generations of Soviet tactical ballistic missiles deployed in the mid 1960s and late 1970s, respectively.

For the warhead effectiveness question, the dominant factor in determining the effectiveness of the several types of warheads accessible to the potentially hostile regional powers is the targeting accuracy. Chemical warheads are available and could be highly effective against US deployment bases for RPBM accuracies in the "nominal" to "optimistic" range. Chemical warheads filled with nerve agent could pose a limited threat even for the "pessimistic" accuracy. For the "optimistic" RPBM accuracy, warheads with multiple submunitions would be effective against deployment bases. However, unitary high explosive warheads would not provide reasonable confidence of significant damage to a deployment base even for the "optimistic" accuracy. If potentially hostile regional

powers acquire nuclear warheads. RPBM's could potentially be effective against deployment bases for any of the accuracy levels considered depending on the warhead yield available.

Therefore, in summary, missiles that will become available to the potentially hostile regional powers well before the year 2000 could target US deployment bases throughout the North Africa/Middle East/Southwest Asia region and the Northeast Asia region. Furthermore, some of the warhead options accessible to those powers would be effective for the range of accuracies projected for those missiles. Chemical warheads already accessible to the potentially hostile regional powers would be effective at any accuracy level considered, and other warhead options such as submunitions will become effective as improved accuracies are achieved.

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GLOSSARY

CEP	Circular Error Probable or Circle of Equal Probability
CRS	Congressional Research Service
DCI	Director of Central Intelligence
DIA	Defense Intelligence Agency
GCP	Geodetic Control Point
GPS	Global Positioning System
ICBM	Intercontinental Ballistic Missile
INF	Intermediate-Range Nuclear Forces
IRBM	Intermediate Range Ballistic Missile
kt	kiloton (nuclear explosive yield)
MTCR	Missile Technology Control Regime
nmi	nautical mile
RLG	Ring Laser Gyro
RMS	Root-Mean-Squared
RPBM	Regional Power Ballistic Missile
TBM	Tactical Ballistic Missile or Theater Ballistic Missile
TEL	Transporter-Erector-Launcher
WGS	World Geodetic System